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PRINCIPLES OF PHYSIOLOGY.

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PROF. CHARLES A. KOFOID AND
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PRINCIPLES OF PHYSIOLOGY;

DESIGNED FOR THE USE OF

SCHOOLS, ACADEMIES, COLLEGES, AND THE GENERAL READER.

COMPRISING

A FAMILIAR EXPLANATION

OF THE

STRUCTURE AND FUNCTIONS OF THE ORGANS OF MAN,

ILLUSTRATED BY COMPARATIVE REFERENCE TO THOSE OF THE INFERIOR ANIMALS.

ALSO,

AN ESSAY ON THE PRESERVATION OF HEALTH.

WITH FOURTEEN QUARTO PLATES AND OVER EIGHTY ENGRAVINGS ON WOOD,
MAKING IN ALL NEARLY TWO HUNDRED FIGURES.

BY

J. C. COMSTOCK AND B. N. COMINGS, M. D.

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PREFACE.

The Science of Physiology, as well as that of Zöology, in its different departments, has for several years formed a prominent branch of study in the best European systems of Education. In France, especially, great attention has been paid to these subjects, and the most distinguished scientific men of that country have not thought it beneath them to write treatises expressly for elementary instruction and for popular use. In the United States, however, until recently, Physiology has not been included in the course of study pursued in Colleges, and has been introduced into comparatively few of our Academies and Common Schools.

In most Institutions it has been looked upon as a matter of secondary importance, rather than as a Science of great practical interest and value to every individual. Medical Schools, alone, have been provided with ample facilities for investigating the structure of the human body; and a knowledge of the functions of the various organs, as well as the proper means of preserving them in health, has been regarded as the peculiar prerogative of professed physicians, and as a mystery too deep and too difficult for the comprehension of others. Happily, this state of things is now beginning to be changed. It has been discovered that there are few portions of the Science which any young person of ordinary intelligence cannot be made to understand and to explain. The knowledge already diffused is creating a demand for more, and Physiology will soon take its appropriate place as a necessary branch of popular education.

This Science has, indeed, peculiar claims to the attention of every teacher who would be successful in his profession, and of every person in any way interested in the education of the young. There is no species of knowledge more valuable to him who has the care of young persons, than that which leads him to appreciate the mutual dependence of the physical and intellectual powers. For want of such knowledge, the ill-judged efforts of many well-meaning teachers have been productive of the most serious evils to their pupils. When those physiological facts which lie at the foundation of mental development shall be fully understood by teachers, then only will their success become perfect, both in imparting information to their pupils, and in fitting them for the arduous duties of life.

Keeping these considerations in view, in the preparation of this work, the principles of the Science have been presented as fully and clearly as the limits of the work would seem to allow; the object having been to bring them separately before the mind, without following them into all the details of their various applications. When the student has once gained a competent knowledge of the principles of Physiology, he will not be slow to perceive their bearing upon the practical training of the body, and their importance to the welfare of mankind.

Brief comparative descriptions of the structure of some of the lower orders of animals have been introduced, for the purpose of giving variety and interest to the study, and of furnishing the teacher with practical demonstrations of the relative value of each organ in the system. Few persons ever enjoy an opportunity of actually examining any of the internal organs of man, while many of the lower animals are easily accessible to investigation; and nothing is more interesting, or better calculated to give clear ideas of our own structure, than the examination of that of these animals.

A distinct chapter has been assigned to the subject of Hygiene, or the Preservation of Health. It is supposed that this subject may be studied in this way better than in detached portions, in connexion with the structure and functions of separate organs. The main object of this chapter is, to show that the duration of human life corresponds very nearly with the comparative physical condition of families, communities, and nations; and that each individual is the guardian of his own health and happiness, and may, to a very great extent, avoid or induce disease, in proportion as he obeys or disobeys the laws of his own organization. The most important rules of Hygiene are stated, with familiar instruction as to the best means of preserving health.

It will be observed, by the reader who has made progress in physiological studies, that many of the engravings, as also parts of several chapters, have been copied from the admirable "Animal Physiology" of Dr. Carpenter. In addition to this and other works of the same author, those of Wilson, Warren, Pereira, Bourgery, Aitken, Roget, Kirkes and Paget, Wyman, and other standard writers, have been consulted. The beautiful "Microscopic Anatomy" of Dr. Hassall has also furnished several figures.

The quarto, or atlas-form, has been adopted in deference to the advice of experienced teachers. This form gives opportunity to make the plates large and complete, the full-length figures being eight inches in height. The wood-cuts were executed by Mr. S. H. Clark, of Hartford; and it is believed that both these and the plates are not inferior to any similar illustrations ever published in this country.

To Professor Brocklesby, of Trinity College, Hartford; to Dr. J. L. Comstock, of Hartford; and also to several excellent teachers, thanks are due for many judicious suggestions, and for other favors received during the preparation of the work.

HARTFORD, *April*, 1851.

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HINTS TO TEACHERS.

From our own experience, we can confidently assure teachers that no branch of education can be made more attractive to the young than Physiology. But the interest which pupils take in any study, is to a very great extent a reflex influence from the teacher's own mind. When a teacher attempts to instruct a class with a mind uninformed or uninterested in the subject of the recitation, the fact will invariably be made manifest in his eye, his features, or his voice; the impressions will be communicated to his pupils with telegraphic despatch, and will lead their minds to act in sympathy with his. But when the teacher enters upon his duties with a zeal kindled by actual knowledge, he will not fail to witness a corresponding enthusiasm in his pupils, provided the study is adapted to their minds.

With what success we have labored to adapt this book to the mind of the young, it is for the public, and especially for teachers, to judge. We have placed questions at the foot of each page, for the aid of such teachers as have not enjoyed opportunities to become thoroughly familiar with the principles of Physiology; but we would recommend to all, as far as practicable, to make their own questions, and not allow their pupils to feel that they are to study only for the answers; nor should they be required to give the answers in the language of the author.

We trust it will be found that almost any scholar of twelve or fourteen years, can be interested and profited by this study. It has been our object not to write all that can be written on the science, but to give only the most important principles; believing that a few truths, fully appreciated, are more valuable, and exert a better influence on the mind, than a mass of information which produces confusion, and is soon forgotten.

But it is hoped that teachers will be able to avail themselves of lectures and of other works, which will carry their knowledge to a higher perfection than can be attained by the study of any one book. Every author has his own peculiar way of presenting truth, and each one will be likely to excel in discussing some one subject with more fullness or force than others. In Physiology, above all sciences, the teacher can find an almost infinite variety of illustrations, if he consults the numerous authors who have written on the subject.

Much interest may be added to the study by examining before the class the organs of the inferior animals. The ingenuity of the teacher will also suggest other experiments that will serve to impress the lesson upon the mind of the learner. The form which primary cells assume when pressing on each other, may be shown by a very simple experiment with soap-bubbles. If a six or eight-ounce vial be filled with water saturated with soap, and then inverted, as the air rushes in to take the place of the water, the vial will be filled with cells of every variety of form and size.

Membrane, muscle, cartilage, bone, nervous matter, &c., and the organs that are formed from these, may all be demonstrated by specimens obtained from the butcher. All specimens of this character should be macerated in water, long enough to render them perfectly clean, before they are presented to the class, and should then be accompanied with a napkin and a tray, to prevent soiling the table and books.—A sharp knife of almost any description, with a pair of sharp-pointed scissors and a pair of forceps, are all the instruments that are necessary for physiological demonstration. By the use of these, almost any organ may be prepared for exhibition to the class. —The lungs and heart may be taken from almost any of our domestic animals, unless the lungs of a horse or an ox should be found too large for convenience. By inserting a stop-cock into the trachea, the lungs may be inflated to their full capacity of distention. The air may then be allowed to escape, and the lungs be again inflated, performing thereby a kind of artificial respiration.

A very beautiful preparation, to show the distribution of the blood-vessels over the membrane of the lung, together with the membrane itself, may be prepared from the lungs of a turtle. Procure a turtle at least six or eight inches in length, cut off the head, and immediately saw the lower shell from the upper at the sides, and then with a knife dissect off the muscles from the shell. When the shell is removed, almost the first object that arrests the attention is the heart, still performing its functions with as much apparent regularity as if nothing had happened, which it will continue to do for several hours, though its action grows more and more feeble. On either side of the heart, and partly under the scapulæ, the lungs may be seen in a collapsed state. A quill should be inserted into the trachea, and the lungs inflated, for the purpose of rendering their position more apparent, when they can be easily removed with the scissors, though it must be remarked that the slightest scratch spoils the preparation. As soon as the lungs are removed, they should be inflated to their extremest capacity, a ligature applied to the trachea, and then hung in the air to dry. In half an hour you have an exceedingly handsome and useful preparation, that may be preserved for any length of time.

A heart for examination should have the pericardium separated from the base about half the distance round, so that it may be held in place or turned off at pleasure. To show the valves, the heart may be cut directly across, at half the distance from the base to the centre, taking care not to cut the little cords that attach the tricuspid and bicuspid valves to the walls of each ventricle. To show the semi-lunar valves, the aorta and pulmonary artery should be cut off, according to the size of the specimen, from half an inch to an inch above their origin. The remaining portions of the heart can then be examined without difficulty.

A very interesting experiment, to illustrate the importance of ventilation, may be made by lowering a lighted taper or candle, attached to a flexible wire, into an open-mouthed glass jar, holding one or more pints. In a very few minutes, carbonic acid will be formed sufficient to extinguish the taper. That it is carbonic acid may be ascertained by pouring into the jar lime-water, which immediately becomes turbid from the formation of carbonate of lime. That carbonic acid is also produced by respiration, may be made to appear by filling and inverting the jar in water; then pass the end of a tube (or, if nothing better be at hand, an open straw) under the jar, and breathe through the tube into the jar till the water is entirely displaced. The hand or a piece of glass or of brown paper must now be put snugly on the mouth of the jar, which is to be inverted, and placed on the table. On removing the hand, plunge the taper into the respired air, and it will be instantly extinguished.—The necessity for a supply of oxygen may be shown by inverting the jar, and passing up the lighted taper: as fast as the oxygen is consumed, the nitrogen, which is lighter than atmospheric air, occupies the upper portion of the jar, causing the taper to grow dim or be extinguished, according to the position in which it is held.

For the purpose of illustrating the subject of digestion, the teeth and stomachs of the rodentia, the graminivorous, the carnivorous, and the omnivorous animals, can be easily obtained. The stomachs should be thoroughly washed, and inflated with air, or stuffed with cotton, hay, or hair.

To obtain the brain of any animal, the skull must be sawed through completely round the head, and, if possible, its membranes must not be ruptured till the brain is removed from the cranium. The brain should then be rinsed with water, and immersed in alcohol for a few hours, or it may be preserved in alcohol as long as desired.

A great variety of interesting experiments, illustrative of the reflex functions of the spinal cord, may be performed on decapitated frogs or turtles.

The ear and eye both require the skill of an anatomist for their dissection. The structure of the tympanum of the ear, however, may be shown very easily by removing the skin from the head of a fowl or a bird, and cutting off with a strong pair of scissors the bone around the external ear till the tympanum is distinctly seen, supported by the stapes. If about one-fourth of the head be now removed, the whole internal structure of the ear may be seen, with the auditory nerve, the vestibule, and cochlea.—It is very easy to cut open the eye, so as to exhibit the aqueous and vitreous humors, the crystalline lens, the iris, the pigmentum nigrum, and the sclerotic coat, but the retina requires more care. To show the retina, take the fresh eye of an ox, clip off the muscular and adipose substance about it, then describe with the knife a circle about the entrance of the optic nerve that shall include one-fourth of the ball of the eye; holding the eye in the thumb and fingers of the left hand, gradually and carefully cut through the sclerotic to the choroid coat, at a single point in the circle already described, and then complete the dissection in water by carefully insinuating the sharp point of the scissors between the coats, and clipping round the circle. The slight attachment of the choroid to the sclerotic may now be separated with the back of the knife till the detached portion of the sclerotic can be clipped off, leaving the nerve entire. The dissection is now complete; and, if well performed, inverted images of objects can be seen on the retina as in life.

The above demonstrations, though so simple as to be easily performed by almost any one, will add much interest to the study. A teacher who has enjoyed the advantages of a dissecting-room, will of course have learned a more scientific way of demonstrating than we have described for the uninitiated.

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PRINCIPLES OF PHYSIOLOGY.

INTRODUCTION.

1. All bodies in which the phenomena of life have been observed, are formed of diverse mutually adapted parts, or *organs*. Such bodies are therefore called *organisms*, or *organized* bodies. Their composition and structure, being peculiar, are named *organic*, and constitute their *organization*. While alive, also, they manifest certain peculiar *vital* properties and modes of action.

2. The various races of organized beings may be studied in two ways. By the aid of the knife they may be separated into the various organs of which they are composed; by the aid of the microscope, the various tissues which enter into the composition of these organs may be examined; and by the aid of chemistry, the ultimate elements of which these tissues consist may be determined. This mode of investigation is applied chiefly to the dead body, and the science derived from it is called *Anatomy*.

3. Anatomy (signifying literally a *cutting up*) therefore, since it teaches us only such facts as are found to exist in the lifeless body, gives but an imperfect idea of the purposes for which living structures were made. To acquire a more complete knowledge, we must adopt a different method of investigation, and observe the various phenomena which organized beings display during their life. We must investigate the means by which these phenomena are produced, and determine, if possible, the laws by which the vital processes are carried on. The knowledge thus obtained constitutes the science of *Physiology*.

4. Thus, Anatomy makes us acquainted with the organs or *instruments* of life, their number, size, situation, form, color, texture, composition, and relation to each other. Physiology teaches the *uses* and *purposes* of these organs. Anatomy makes known the *means;* Physiology the *ends*. To study Anatomy without Physiology, would be like gaining a knowledge of the separate parts of a steam-engine, without learning its mode of action or the purposes to which it can be applied. And to study Physiology without Anatomy, would be like observing the progress of a train of rail-road cars, without knowing the means by which they are propelled. In this work, therefore, such anatomical description will be introduced, as will suffice for the better understanding and illustration of the phenomena which it is the office of Physiology to examine.

5. The two sciences, ANATOMY and PHYSIOLOGY, in their most extended application, take cognizance of all organized beings, whether animal or vegetable. These sciences are, however, naturally divided into several branches, according to the particular departments of the organic world to which they are applied. Thus we have the primary branches of ANIMAL PHYSIOLOGY and VEGETABLE PHYSIOLOGY, each of which is confined exclusively to the great natural department which gives it its title. Animal Physiology is again divided into COMPARATIVE PHYSIOLOGY, and HUMAN PHYSIOLOGY, the first of which is limited in its application to the lower orders of animals, and the latter to man. The same divisions are made of the science of Anatomy.

6. Notwithstanding these divisions, however, there is, strictly speaking, no Physiology peculiar to any single being or class of beings, as Man for example; and to study the phenomena exhibited by one individual would give us as imperfect a knowledge of Physiology as a person would obtain of Astronomy by studying the motions of a single star. For if we examine any one organ and the function it performs, in a certain given animal, and then refer to any other animal, we shall usually find a repetition of that organ, or some modification of it, in that other animal. And this law is so general as to apply to nearly the whole series of animated beings. The essential process of respiration, for instance, is the same in all animals, and some form of the lung, the organ by which that process is carried on, greatly varied to be sure, and sometimes scarcely recognizable, is found in nearly every group of breathing organisms, from the insect to the man. By a comparative view of the various complications of any particular organ, as found in the different groups, we arrive at what is essential to constitute such an organ, and what is the relative importance of its function to the maintenance of life.

7. It is the design of this work, then, to teach the principles of Human Physiology, and to illustrate that science by reference to Comparative and Vegetable Physiology, whenever such illustration will add to the interest or assist in the comprehension of the main subject.

CHARACTERISTICS OF ORGANIC AND INORGANIC MATTER.

8. Matter is presented to our senses in an almost infinite variety of forms, compounds, and organizations. The earth itself is an aggregation of compounds, each possessing properties and characteristics peculiar to itself. The surface of the earth, including the water and the air, teems with myriads of organisms, each differing from the other in the combination of its elementary parts. Yet, when subjected to the examination of the chemist, it is found that there are only *fifty-five* individual elements out of which all this endless variety of matter is composed. An explanation of this great truth in nature is found in the fact that the variety which we behold exists in the inherent power of these few elements to develope new properties and new phenomena with each new combination. Thus carbon and oxygen form carbonic acid (a poisonous gas); oxygen and hydrogen form water; oxygen and nitrogen form the air we breathe; nitrogen and hydrogen form ammonia; carbonic acid and ammonia form carbonate of ammonia. Here, then, are four elements forming five different combinations, and each compound is wholly unlike the others.

9. Now, if a piece of granite is broken from the rock which has withstood the waste of centuries, it is found to retain all the characters and properties which it possessed at its creation. If it is divided and subdivided, or even ground to powder, the same is true of every individual particle. But if you cut a rose from its stem, or amputate the arm of a man or the leg of a dog, they no longer possess the same properties which belonged to them while forming a part of the plant or the animal. They become withered and decomposed, their appearance and texture become changed, and they finally decay and are lost to the senses. The granite exists independently of any particular shape or any determinate organization. Its structure and composition, unless when some foreign decomposing agent is applied to it, are always the same. The rose, on the other hand, requires certain conditions, such as warmth, moisture, and light, and connexion with its parent stem, to maintain its existence; and the arm requires the circulation of the blood through its veins and arteries, and the purification of that blood by respiration, for the same purpose. The granite, also, has no particular part which is different from any other part, or which performs any separate office. The plant and the animal, on the contrary, possess certain organs or instruments, such as roots and leaves in the one, and lungs and stomach in the other, by which those acts necessary to their existence are performed. Here then is suggested the idea of the two great divisions of matter. Hence matter as it exists in animals and vegetables is called *organic* or *organized*, and in minerals *inorganic* or *unorganized*.

§ 1. What are organized bodies?—Why are they so called? 2. What is the first way in which organized bodies may be studied?—What is the science derived from this mode of investigation? 3. What does the word *Anatomy* signify?—Does it give a perfect idea of organized beings?—How is a more perfect knowledge obtained?—What science does this knowledge constitute? 4. What does Anatomy teach us?—What does Physiology teach us?—How is the difference between those sciences illustrated? 5. Into what branches are Anatomy and Physiology divided?—Define these different branches. 6. What is said of the utility of studying comparative Physiology?

§ 7. What is the design of this work? 8. Of how many individual elements is matter composed?—What is the reason of the great variety of forms which matter assumes?—How is this illustrated? 9. Does any change take place in a piece of granite, when it is broken from the rock?—What changes take place in a part of a plant or an animal, when separated?—Explain the reason of this difference.—How then does organic matter differ from inorganic, and what divisions are founded on this difference?

10. Nevertheless, the same elements which exist in organized structures, are found in the more simple combinations of unorganized matter. No new or distinctive element, then, can characterize either plants or animals. The cause of the distinctive characteristics of these two great departments of animated existence must, therefore, be found in chemical combinations dissimilar to those which enter into the composition of inorganic matter. Chemical analysis proves this inference to be correct.

11. In the inorganic world, most substances are either in the elemental state, or are formed by the union of only two elements. In plants the most abundant substances are compounds of three elements, carbon, hydrogen, and oxygen, which, by combining with each other in different proportions, form starch, sugar, and other vegetable productions. In animals, the most abundant substances are composed of four or five elements. Albumen, fibrine, gelatine, for instance, are compounds of oxygen, hydrogen, nitrogen, carbon, and sulphur. The number of combinations of elements in plants is greater than in inorganic compounds, and the number in animals is greater than in either. It is also true that in both classes there is a great number of compounds formed from a few elements, and a large number of atoms or equivalents of each element unite to form one equivalent or atom of the compound. Now, it is a general rule that the greater the number of atoms that unite to form a compound, the less is the stability of that compound. Hence it is that inorganic compounds are decomposed only by the most powerful agents, and are consequently enabled to retain their original character for an almost unlimited period of time. Vegetable compounds, on the other hand, are decomposed with comparative ease, and animal compounds are held together with such comparatively slight affinities that they are said to decompose spontaneously, the presence of atmospheric air being the only condition requisite for the occurrence of that phenomenon.

12. All organized bodies have a limited period of life, which varies with every species. In some this period is confined to a single day —in many plants to a single summer; while some animals live more than a century, and some trees, as the oak and olive, are supposed sometimes to live a thousand years. In all, the perpetuity of the species is provided for by the power of *reproduction*, which is possessed by both animals and plants. The life of each individual is maintained during its appointed period, by a process called *nutrition*, which consists in imbibing external substances, and appropriating them to its own use. Vegetables receive their nutriment from the earth and air around them, and interpose the new particles between those which already form their substance. Animals obtain their nutriment from the organized substances contained in plants and in other animals, and adapt it to the maintenance of their own life by the action of certain organs with which they are furnished for that purpose.

13. Thus each of the great departments of nature contributes to sustain the other. The unorganized substances maintain the life and growth of the vegetable, which in its turn affords food and nutriment to the animal; and both vegetable and animal, after fulfilling their destined period of existence, die, decompose, and give back to the inorganic world the elements which they derived from it. Matter is thus constantly undergoing a series of changes—reproduction and decomposition, life and death. Every particle in the vast world of matter is contributing its aid to maintain the laws of nature, in perfect obedience to the mandates of the Great Designer, who is thus exhibiting to us the inexhaustible resources of that Wisdom which can develop, from means apparently so limited, such an infinite variety of forms and structures, all mutually nourishing and sustaining each other. So true is this, that no part of the earth is so barren, no desert is so parched, that it may not be inhabited by some form of life, and even the hardest rock holds in its smallest crevice something for the support of vegetable existence. There is no organized being that may not in some way afford nutriment to other organisms. No plant is so poisonous as not to be fed upon by some species of insect, or so compact in its structure as to be able to resist the attacks of some little devourer. Of the almost innumerable species of insects, some prey upon other insect forms, some upon the larger animals; some live upon decayed wood, and some burrow into the hardest substance of the most lofty trees. Some feed upon the root, some upon the foliage, and others draw nectar from the delicate flowers. All these, in their turn, become food for animals of higher organization, and the latter satiate their voracious appetite upon each other. Some become victims while the life-blood is yet warm in its vessels, and others die of natural causes, and around them gathers an innumerable throng of eaters. No animal is so large that it is not soon consumed by the insatiate host, and none so offensive that there is not some fouler form to prey upon its remains. And the rule has no exception, not even in him who in the height of his pride and power exalts himself above the inferior creation;

> "For when all is past, it is humbling to tread
> O'er the weltering field of the tombless dead,
> And see worms of the earth and fowls of the air,
> Beasts of the forest, all gathering there;
> All regarding Man as their prey,
> All rejoicing in his decay."

DISTINCTIONS BETWEEN ANIMALS AND PLANTS.

14. In the higher and more perfect forms of animal and vegetable life, there can be no difficulty in distinguishing between an animal and a plant. But when we examine some of the lower orders, it is by no means easy to determine where animal life ends and vegetable life begins. Indeed, there seems to be an intermediate group, sometimes called Plant-animals, as to the nature of which naturalists themselves have hardly been able to agree. The Sponge, for instance, has been repeatedly transferred from the animal to the vegetable kingdom, and back again, as new properties have been discovered in it, until we are yet somewhat doubtful to which it rightfully belongs.

15. Passing by this ambiguous class of organisms, we shall find that the two properties of animals, by which they are always to be distinguished from plants, are *sensation* and *voluntary motion*. Some vegetables, it is true, possess a certain kind of motion. The leaves of the sensitive-plant fold together, and droop from the stem, at a touch of the finger, but this movement is owing to a physical change produced in the leaf, and by no means to any feeling or sensibility such as induces a man to withdraw his hand when it comes in contact with fire. The plant manifests no *consciousness*, and therefore cannot be said to possess sensibility. Sensibility and the power of spontaneous motion are therefore called the functions of *animal* life, and every being which is conscious, in however slight a degree, of its own condition, and of the circumstances affecting it, must be regarded as an animal.

Another mark of distinction peculiar to animals, is that they always possess a *stomach* or digestive cavity of some kind. Since vegetables obtain their food directly from the earth and air, in the form of a liquid or a gas, they have no need of a cavity in which to receive and prepare it. Animals, on the other hand, since they live upon organized substances, require a cavity in which to dissolve and reduce their food to a fluid form, so as to absorb its elements into their tissues.

In vegetables, again, the *circulation* is much more simple than in animals. They have no heart or special organ for the distribution of their sap.

These distinctions may be summed up as follows:

ANIMALS.	PLANTS.
Motions voluntary.	Motions involuntary.
Possessing sensation.	Without sensation.
With a digestive cavity.	Without a digestive cavity.
Nourished by organic matter.	Nourished by inorganic matter.
Consume organic elements, such as starch, sugar, &c.	Produce organic elements, such as starch, sugar, &c.

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§ 10. Are the same elements found in organic and inorganic matter?—What then is the cause of the distinctive characteristics of organized matter?—How is this proved to be true? 11. Of how many elements are inorganic substances composed?—Of how many elements are the most abundant substances in plants composed?—In animals?—What example is given of this?—What is the general rule as to the stability of a compound substance?—What then is the reason that vegetable and animal substances are more easily decomposed than minerals?—What is the condition requisite for the decomposition of animal substances? 12. What is said of the period of life of organized bodies?—What examples are given?—How are the species perpetuated?—How is the life of each individual maintained?—How do vegetables receive their nutriment?—How do animals obtain theirs? 13. How do the organic and inorganic worlds sustain each other?—What changes is matter constantly undergoing?—What remarks are made on this subject?

§ 14. What is said of the difficulty in distinguishing plants from animals?—What of the Sponge? 15. What are the two distinguishing properties of animals?—What is said of the motion of plants?—What other peculiarity do animals possess?—Why do animals need a stomach, and vegetables not?—How does the circulation in vegetables differ from that in animals?—Give the summary of these distinctions.

CHAPTER I.

CHEMICAL COMPOSITION OF ANIMAL BODIES.

16. THE animal body is composed of fluids and solids. The quantity of fluids far exceeds that of solids, though it is a difficult matter to form an entirely correct estimate of their relative proportions. By exposure to a process of evaporation, a body weighing one hundred and fifty pounds may be reduced to twelve or fifteen. Perfectly dry mummies are sometimes found to weigh only seven or eight pounds. The amount of fluid which can be drawn directly from the body is only about thirty pounds. The fluids vary exceedingly at different periods of life. In youth they are very abundant, making the form plump and round. In old age they are greatly diminished in quantity, leaving the form shrunken and wrinkled.

Animal fluids are of two kinds, *formative* and *secreted*. The formative fluids contain in solution the materials for the formation of the solid tissues. The secreted fluids are separated from the tissues and the blood, and are the medium through which all the waste particles are carried out of the system. The chemical elements are not essentially different in the solids and the fluids, both being alternately converted into each other.

17. Seventeen out of the fifty-five elementary substances of which all known matter is composed, may be obtained by analysis from the human body. These are oxygen, hydrogen, nitrogen, carbon, sulphur, phosphorus, silicon, chlorine, fluorine, potassium, sodium, calcium, magnesium, iron, and sometimes manganesium, aluminum, and copper.

18. Oxygen, hydrogen, nitrogen, and carbon, are called *essential elements*, because they exist in nearly all animal substances, and form the largest part of all. The remaining thirteen are less constant, and occur only in small quantities, and in combination with the essential elements.

19. The simplest of the compounds naturally formed in the body are called *Proximate Principles*, because they are supposed to be in order of simplicity nearest the elements. They are composed of at least three of the elements. The most essential of the proximate principles are *Albumen*, *Fibrine*, *Caseine*, *Gelatine*, and *Hæmatosine*.

20. *Albumen*, composed of oxygen, hydrogen, nitrogen, carbon, and sulphur, is found solid in the brain, spinal cord, and nerves, and in the mucous membrane; fluid in the serum of the blood, and in lymph and chyle. The white of eggs is almost entirely composed of it. It is perfectly colorless when pure, and is coagulated or hardened by heat and by acids.

21. *Fibrine*, composed of the same elements, is the most abundant of animal substances. It is the basis of the muscles, and is found in the chyle, lymph, and blood. It coagulates spontaneously.

22. *Caseine* has many properties in common with albumen and fibrine. It exists in the greatest abundance in milk, and is the basis of cheese.

23. *Gelatine* is the chief constituent of the cellular or areolar tissue, skin, tendons, ligaments, cartilages, and bones. It is obtained by boiling either of these substances, and allowing the solution to cool. Glue is an impure gelatine.

24. *Hæmatine* or *Hæmatosine* is the red coloring matter of the blood.

The chief characters of the animal proximate principles are as follows: They all contain carbon, oxygen, and hydrogen, and most of them also nitrogen. They are all decomposed by a red heat, and are for the most part exceedingly prone to putrefaction.

25. There is a class of substances called *secondary* compounds, which are formed from the elements of the tissues, to be excreted from the system by particular organs. Some of these are *urea*, *uric acid*, *cholestrine*, *pepsine*, *sugar of milk*, and *lactic acid*. The most important animal compounds have thus been enumerated, and others of less abundance and importance are omitted.

§ 16. Of what is the animal body composed?—Which of these parts exists in the greatest abundance?—How is this proved?—Is the proportionate quantity of the fluids the same at all periods of life?—What effects are produced by this variance?—What are the two kinds of animal fluid?—Define them.—Is the chemical composition of the fluids different from that of the solids? 17. How many of the elementary substances are found in the human body?—What are they? 18. What are the essential elements, and why are they so called? 19. What are the Proximate Principles?—Of how many elements are they composed?—Which are the most essential of them? 20. Describe albumen and its composition. 21. What is fibrine? 22. Where is caseine most abundantly found? 23. What is gelatine, and how is it obtained? 24. What is hæmatosine?—What are the chief characters of animal proximate principles? 25. What are some of the secondary compounds?

CHAPTER II.

STRUCTURAL COMPOSITION OF THE HUMAN BODY.

26. CERTAIN primary forms of the solids may be observed, which, by their various modifications and modes of combination, make up the tissues and organs of the human body. The simplest and most minute of these primary forms are *granules* or *molecules*. They are particles of various sizes, from immeasurable minuteness to the ten thousandth of an inch in diameter. Granules are found floating in milk, chyle, and other animal fluids, and imbedded in most of the tissues.

27. *Nuclei*, or *corpuscles*, are found connected with cells, or tissues formed from cells. They are the germ or centre around which cells are formed.

28. *Cells*, *primary* or *elementary cells*, are minute bubbles, vesicles, or scales, larger than the nuclei, and usually filled with liquid contents. Most of the cells in the human body contain nuclei.

29. The natural shape of the cell is oval or spheroidal, but they often become flattened or many-sided by pressure. Their contents are various, according to their position, office, and age. The cells perform a highly important process in the animal economy, since they form all the tissues of the body, either directly by their deposition, or by elaborating the fluids from which the tissues are derived. They are concerned not only in the function of nutrition, in the development and restoration of parts, but in absorption and secretion. They are developed into tissues in various ways. In some, the cell-membranes become elongated, and are folded and divided into threads or filaments of exceeding fineness. Several elongated cells are joined end to end, the partitions at each end being removed, when they constitute *tubules* or little tubes.

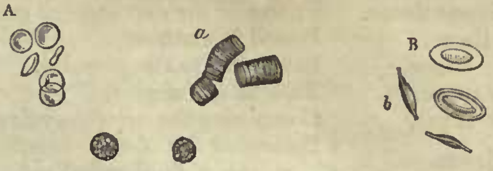

Fig. 1.—*A.* Corpuscles of human blood, magnified five hundred diameters. *a.* Particles collected in a columnar form. *B.* Red particles of the blood of the common fowl. *b.* A particle seen edgeways.

By the farther development of tissue, other forms are produced, such as,

30. *Filaments*, or *fibrils*, which are exceedingly delicate threads, composed of minute particles, and usually arranged in parallel bundles, or *fasciculi*.

31. *Fibres* are larger than filaments or fibrils, but are similar to them in other respects.

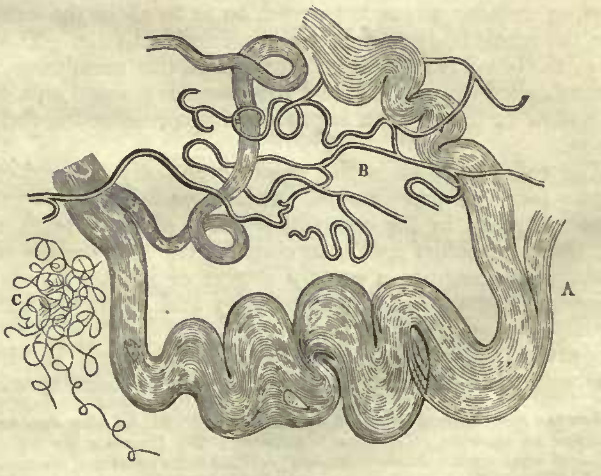

Fig. 2.—Fasciculi and fibres of cellular tissue. *A.* White fibrous element, with cell-nuclei visible in it. *B.* Yellow fibrous element, showing its branching fibrils. *C.* Finer fibrils of the yellow element.

§ 26. What are granules or molecules, and where are they found? 27. What are nuclei, or corpuscles? 28. What are cells? 29. What is their shape and office?—How are tubules constituted?—What is represented in Fig. 1? 30. What is a filament? 31. What is a fibre?—Describe Fig. 2.

32. A *tissue* is formed by the union of one or more of these primary structures.

33. An *organ* is any solid part of the body. It is an instrument by which some function is performed. Thus the heart is an organ, and its function is to propel the blood through the vessels.

34. An *apparatus* consists of a number of different organs, arranged for the performance of some one office. Thus the digestive apparatus consists of the teeth, mouth, stomach, intestines, &c.

35. A *system* is a connected series of similar parts, such as the muscular system, the nervous system.

36. The different organs of the body are made up of one or more tissues or textures, according as they are of a more simple or a more complex structure. These tissues are made up of the elementary particles already described, and each of them performs the same function, in whatever part of the body it exists. Most of the organs are composed of a variety of these tissues, which are spread into membranes, collected into cords, or hollowed out into canals, and by their diversity of combination, figure, and color, they produce all the varieties of structure and function possessed by different organs. Some anatomists consider that in every animal there are as many different tissues as there are varieties of solid parts, and describe skin, bone, muscle, nerve, and every other solid, as a distinct tissue.

37. The number of tissues in the human body is variously stated. The following list seems to include all those which are considered to be ascertained by the latest writers:

1. Corpuscular tissue.	Found in the blood, lymph, and chyle.
2. Epidermoid tissue.	In the skin, hair, and nails. [coat.
3. Pigmentary tissue.	In a coat of the eye, called the choroid
4. Adipose tissue.	The fatty parts of the body.
5. Cellular tissue.	The primary organization of the cells.
6. Fibrous tissue.	Composed of connected fibres.
7. Elastic tissue.	Constitutes the middle coat of arteries.
8. Cartilaginous tissue.	Found in the cartilage or gristle.
9. Osseous tissue.	Found in the bones.
10. Muscular tissue.	Belonging to the muscles.
11. Nervous tissue.	That of the nerves. [atics.
12. Vascular tissue.	Composing the arteries, veins, and lymph-
13. Serous tissue.	Belonging to those membranes which secrete a fluid called serum.
14. Mucous tissue.	That of those parts which secrete mucus.
15. Dermoid tissue.	Found in one layer of the skin.
16. Glandular tissue.	That which forms the glands.
17. Refracting tissue.	That of the cornea or lens of the eye.
18. Petrous tissue.	That of the enamel or ivory of the teeth.

38. The cellular or areolar tissue or membrane is regarded as the primary form of all the others. It is formed by the crossing or interlacing of minute fibres, interwoven in every direction so as to leave innumerable small spaces, which communicate with each other, as is shown by filling them with air or water. When the lung and the surrounding cellular tissue is pierced, so as to allow the external air to enter, the whole body may become inflated with air. The watery portion of the blood is sometimes effused into this membrane, causing the disease called dropsy. When the finger is pressed on a dropsical limb, a hollow or indentation is produced by pressing the fluid out of this tissue.

39. The cellular tissue is the most extensively diffused of all the elementary forms of organization. It is to be found in every part of the system, except in the compact portions of bone, teeth, and cartilage. One of its chief uses is to connect together organs and parts of organs, which require a certain degree of motion on each other. It possesses great power of extensibility and elasticity, but neither contractility nor sensibility.

40. Most of the varieties of this membrane will be described together with the organs in which it is found; since these organs, or its use in connection with them, give it the various names assigned to it in different positions. Thus, when this membrane incloses those organs not exposed to the air, it is called *serous* membrane, on account of the fluid called *serum*, secreted in it. In the lining of the nose, mouth, stomach, and other parts, it is called *mucous* membrane, from a secretion called *mucus* which is forced out from numerous glands beneath its surface. When it forms a covering or envelop to the body, it receives the name of *dermoid* membrane, or skin.

Fig. 3.—A magnified representation of a portion of areolar tissue.

41. The cellular membrane of itself possesses no sensibility whatever, but when such a provision is necessary, nerves are distributed through it. In all those cavities not exposed to the air, when it forms an envelop for each of the organs, and a lining for the cavity in which they are contained, its use seems to be to suspend the organs, and cause them to glide upon each other with the greatest possible ease. Here it is not supplied with nerves. But in the eye, nose, mouth, lungs, stomach, and other parts, nerves are distributed for the purpose of making these organs sensitive to the presence of such substances as come in contact with its surface. In the skin, the distribution of nerves is most abundant, causing the sense of touch.

VITAL PROPERTIES OF THE ORGANS AND TISSUES.

42. Some of the actions of living bodies indicate the operation of other properties and forces besides those which can be referred to their mere chemical and mechanical organization. These properties produce phenomena peculiar to living beings, and are therefore called *vital properties.* The powers which they exert in maintaining the actions of living beings are called *vital forces.* The actions themselves produced by these properties—as digestion, absorption, secretion, and circulation—are *vital processes*, and the state in which these processes are displayed is *life.*

43. The most general property of living bodies is shown in their ability to *form themselves* out of materials dissimilar to them. As, for example, when a plant grows by appropriating to itself the elements of water, carbonic acid, and ammonia; or when an animal eats vegetables, and its blood and all its various organs are formed out of the materials of its food.

44. This power of self-formation is displayed in three modes, *development*, *growth*, and *assimilation*, or *maintenance.*

45. *Development* is that process by which each tissue or organ is formed.

46. *Growth* is the increase of a part already formed, by the addition of similar materials to those of which that part already consists. It is the process by which parts increase in weight and size.

47. *Assimilation*, or *maintenance*, is that process which supports living bodies in their natural condition, notwithstanding the changes to which they are liable from external influences and from their own natural decay. This result is effected by the continual formation of new particles in the place of those which are worn out and removed.

48. *Contractility* is another vital property. It consists in the power which the tissues of the muscles and of some other parts possess, during life, of contracting or shortening themselves in a peculiar manner. These contractions are produced by various changes, such as the contact of foreign matters, electricity, variations of temperature, &c. These, and whatever other applications will give rise to these contractions, are called *stimuli.*

49. The *power of conducting or transmitting* the impressions produced by stimuli is another vital property. This property belongs

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§ 32. How is a tissue formed? 33. What is an organ? 34. Of what does an apparatus consist?—Give an example. 35. What is a system? 36. How are the different organs made up?—Of what are the tissues composed?—What is the number of the tissues, as here laid down?—What is the first in the list, and where is it found?—The second? &c. 38. How is the cellular tissue or membrane formed?—How is it shown that the cells of this membrane communicate with each other?—What is the reason of the indentation made by pressing upon a dropsied limb?—What does Fig. 3 represent? 39. In what parts of the system is the cellular tissue found?—What is one of its chief uses? 40. What is this membrane called when it incloses organs not exposed to the air?—Why is it so called?—What is it called in the mouth and stomach?—Why is it so called?—When it forms an outer covering, what is it called?

§41. How is sensibility given to this membrane?—In what positions is it destitute of nerves?—In what position is it provided with nerves? 42. What are vital properties?—What are vital forces?—What are vital processes? 43. How is the most general property of living bodies shown?—What examples are given? 44. In what modes is the power of self-formation displayed? 45. What is development? 46. What is growth? 47. What is assimilation? 48. What is contractility?—How are contractions of the tissues produced?—What are stimuli? 49. What is another vital property?—To what system does this property belong?—How is the impression produced by a stimulus conducted?

to the nervous system alone. When a stimulus of any kind is applied to a nerve, the impression is conducted by the nerve throughout its whole length, with unmeasurable rapidity, in the same way as electricity is conducted along a wire.

50. The property of *irritability* belongs also to the muscles and other contractile tissues. It includes both the capacity of receiving a direct stimulus and the power of contracting in consequence thereof.

51. When an impression is conveyed from any part of the body, along a nerve, to the brain, the mind may take cognizance of it; what the mind thus becomes conscious of, is called a *sensation;* and the act of the mind in noticing it, a *perception.* All parts through the nerves of which such sensations may be derived are called sensible or sensitive parts.

CHAPTER III.

CIRCULATION OF THE BLOOD.

52. Nutrition and growth are characteristics of all living beings. Growth, however, is only the result of nutrition, which is essential to both animal and vegetable life. In both animals and vegetables the process of nutrition is carried on by means of a circulating fluid. In plants, this fluid is the sap, which is absorbed directly from the earth or air. In animals, this fluid is called blood. The appearance and character of blood are not the same in different groups of animals. The blood of insects, and that of other lower orders, is white or colorless. In mammalia, birds, reptiles, and fishes, it is of a dark purple color when drawn from a vein, and of a bright scarlet when it comes from an artery. It emits an odor similar to that which arises from the breath or skin of the animal from which it is taken. Thus the strong scent of the pig or the cat, and the peculiar milky smell of the cow, can easily be discovered in their blood.

53. When the blood of man, or of an animal of the higher order, is examined by the microscope, as it flows in the vessels of a living part, it is seen to consist of two distinct substances—a colorless fluid, called *liquor sanguinis* (liquid of the blood), and numerous minute red particles which give the blood its color. These blood-corpuscles or *blood-discs* (§29, fig. 1) are little round cells flattened like a piece of money. These discs in human blood are from 1-2800th to 1-4000th of an inch in diameter. In birds, reptiles, and fishes, they are generally much larger.

54. In a short time after blood is drawn from its vessels, it begins to clot or coagulate and become jelly-like, and the fluid changes into a solid. Soon drops of transparent yellowish liquid, called *serum,* begin to ooze from the surface of the solid clot. The serum continues to increase, until the clot, much diminished in size, floats in it. The reason of these changes is this: the liquor sanguinis, or liquid part of the blood, consists of serum, holding fibrine in solution. The peculiarity of fibrine (§ 21) is to coagulate or become solid spontaneously. When, therefore, the blood is drawn from the vessels, the fibrine begins to coagulate, contracts more and more, presses out the serum, and retains the blood-corpuscles. If the air is excluded from the blood, coagulation takes place more slowly.

The serum or liquid part of the blood, which remains after the coagulation of the fibrine, is composed of several substances (the principal one of which is albumen) dissolved in about nine times their weight in water. The water of the blood is one of its most important constituents, and always forms by far the greater proportion of its bulk, one thousand parts of blood containing from seven hundred to seven hundred and ninety parts of water. It is subject to frequent variation in quantity, according to the period since eating, the amount of bodily exercise, the state of the atmosphere, and many other circumstances. An uniform proportion of water is, however, on the whole, maintained; because all those things which tend to diminish the proportion of water in the blood, such as active exercise and the eating of salt food, also excite thirst, and the water drank to relieve the sensation of thirst goes to restore the original proportion. On the other hand, when an excess of water is drank, it is quickly thrown off from the blood in more copious excretions of sweat and other fluids.

The water also maintains the liquid state of the blood, and gives it its proper degree of adhesion to the vessels, through which it ought to flow with the least possible resistance from friction. On the water also depends the active absorption by the small blood-vessels, into which no fluid will quickly penetrate, unless its density is less than that of the blood. Indeed, the organic life of the several parts of the body is in direct proportion to the quantity of water which they contain. This is illustrated by the blood itself, which is more active in its movements and operations than any other constituent of the system.

Hæmatine, or hæmatosine, the coloring principle of the blood, contains nearly seven per cent. of iron, and it is owing to the fact that this proportion is diminished in certain diseases, that iron is prescribed as a remedy.

The average proportions of the principal constituents of the blood, in one thousand parts, are:

Water, - - - - - - - -	784.
Red corpuscles, - - - - - - -	131.
Albumen of the serum, - - - - -	70.
Saline matters, - - - - - - -	6.03
Fatty and other matters, - - - - -	6.77
Fibrine, - - - - - - - -	2.2
	1000.

55. In the chemical analysis of the blood, we have a remarkable illustration of its fitness to fulfill its most important purpose, that of renovating the tissues. Thus the elements discovered by chemistry in the dried blood of the ox, are combined so exactly in the same proportions as the same elements are in the flesh of the animal, that the elementary composition of the blood and flesh may be considered identical.

56. The office of the blood, then, is to carry nutriment to each of the tissues. At one point it furnishes the elements of bone, at another those of muscle, at another those of the brain, and so on. The blood also takes up and carries off, through appropriate organs, all waste particles; thus maintaining in the body a continuous round of organization and decomposition, of growth and decay—a perpetual change and interchange of particles new and old.

57. It has been supposed that the human organism was subject to a complete renovation once in every seven years. It is, however, impossible to determine how frequently the whole of the refuse matter of the body is thrown off and replaced by new particles; though it is certain that a perpetual and active change is constantly at work to keep the delicate and complicated machinery of our bodies in repair.

58. In order to bring the particles of the blood into immediate contact with the tissues, so that its renovating materials may be absorbed by them, some apparatus is necessary, and we shall soon see how admirably this condition is fulfilled. The organs by means of which the blood is thus carried from one part of the body to the other, constitute the *circulatory apparatus,* and the course of the blood through these organs is called its *circulation.*

59. The circulatory apparatus is more or less perfect and complicated, according as the animal in which it exists has a higher or lower position in the scale of beings, and the quantity and quality of the blood depend upon the same conditions. In the lower orders of animals, where the cavity in which digestion is performed extends through the whole system, so that every part absorbs the nutriment it requires through its own walls, and where the external surface is so constructed as to admit of the free absorption of oxygen from the atmosphere, no necessity exists for the transmission of the fluids from one part to another, and the same cavity, which is simply a sac, or several sacs united together, serves the double purpose of a digestive and a circulating canal.

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§ 50. What is irritability? 51. What is a sensation?—What is a perception?—What are called sensitive parts? 52. How is the process of nutrition carried on?—What is the circulating fluid of plants called?—that of animals?—What is the color of the blood of insects?—of the higher orders of animals?—What is said of its odor? 53. Describe the microscopical appearance of blood.—Describe the blood-discs. 54. What changes take place in the blood after it is drawn from the vessels?—What is the reason of these changes? What are the principal constituents of serum?—What proportion of water is contained in the blood?—How is an uniform proportion of water maintained?—What conditions of the blood depend on its water?—What are the average proportions of the principal constituents of the blood?

§ 55. What is said of the fitness of the blood to renovate the tissues? 56. What, then, is the office of the blood? 57. How often has it been supposed that the whole system undergoes renovation?—Is it possible to determine this with certainty? 58. What is the circulatory apparatus?—What is circulation? 59. What is said of the circulatory apparatus of the lower orders of animals?

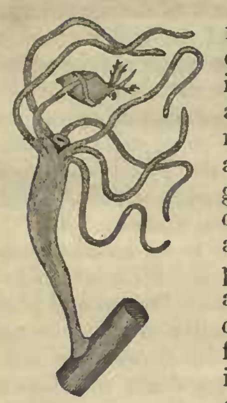


Fig. 4.—THE HYDRA, or Fresh-water Polype.

60. The Hydra, or fresh-water polype, represented in fig. 4, attaches itself to a stick or other floating substance by a kind of sucker at its lower extremity, and stretches out its seven arms in search of food. In the centre, surrounded by these arms, is the mouth of the animal, which leads directly to the stomach or general cavity of the body, in which the food drawn down by the arms is digested and absorbed by the surrounding tissues. Some parts of the nutriment form currents to the arms, and the portions of food not capable of digestion are thrown out at the mouth, thus forming feeble channels of circulation. The internal sac of this animal is only a prolongation of its external covering, and is so much like the latter in structure, that the animal may be turned inside out, and still continue to perform its functions as perfectly as before.

61. As we ascend in the scale of the animal kingdom, we next find that in insects there is a central pulsating vessel running along the back. As different portions of this vessel successively contract, the circulating fluid is forced through numerous valvular openings at various points, throughout its length. At the head, this dorsal vessel (fig. 5), as it is called, divides into two branches, which descend on each side, and again unite to form a long trunk on the under side of the body. This last trunk joins the dorsal vessel at the tail or posterior part of the insect. This kind of circulating system is more fully represented in plate 1, fig. 1. The pulsating canal of the insect seems to be an approximation to a heart with a single cavity.

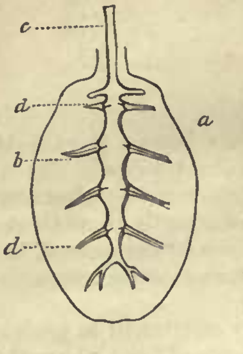


Fig. 5.—DORSAL VESSEL OF THE SPIDER.—*a*, the abdomen; *b*, the dorsal vessel or heart; *c*, a trunk passing to the head; *d*, *d*, vessels communicating with the organs of respiration.

62. In fishes we find a distinct heart, with two cavities, an auricle or reservoir, and a ventricle or propelling organ. The auricle receives the blood as it is returned from the general circulation, and empties it into the ventricle, which, by contracting, propels it into the gills, where it is exposed to the action of the air diffused through the water. The blood absorbs a portion of oxygen from the air, and is then collected into a single large trunk, which distributes it to all the parts. After circulating through the system, the blood again returns to the auricle, is again exposed to the action of the air, and again distributed. A general plan of this mode of circulation is exhibited at fig. 6, and the arrangement of the organs in the body of the fish, at plate 1, fig. 3.

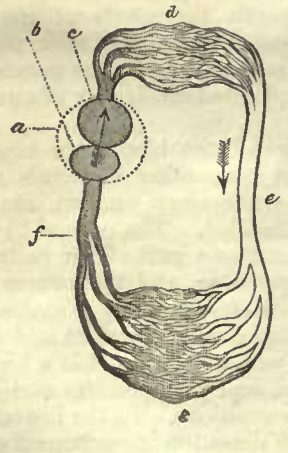


Fig. 6.—CIRCULATION IN FISHES.—*a*, heart; *b*, auricle; *c*, ventricle; *d*, circulation through the gills, or lesser circulation; *g*, circulation through the body, or greater circulation; *e*, arteries; *f*, veins.

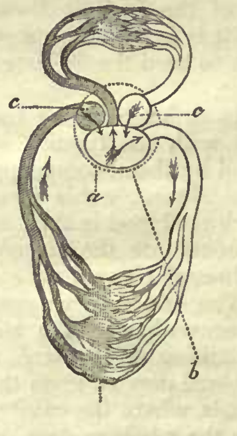


Fig. 7.—CIRCULATION IN REPTILES.—*a*, heart; *b*, ventricle; *c*, *c*, auricles.

63. In the case of reptiles, and the perfect amphibia, such as the frog and the snake, in which only a portion of the blood passes through the lungs, the heart has three cavities, two auricles, and one ventricle. The two auricles receive the blood both from the lungs and from the system, and deliver it to the ventricle, which propels a part to the lungs, and a part to the system. This modification is illustrated by fig. 7, and the anatomy of the organs as displayed in the lizard is shown in plate 1, fig. 4.

64. Finally, in the mammalia, to which man belongs, and in birds, we find the circulatory apparatus still more perfect and more complicated. Instead of a single heart with two cavities, we have a double heart with four cavities. The human heart is situated in the front part of the thorax, between the lungs. Its form is somewhat like that of a pear, with its base or broader part upward, inclining backward and to the right—its apex or point being forward and to the left. When the heart contracts, its apex is tilted forward so as to strike against the walls of the thorax, between the fifth and sixth ribs of the left side, where its beatings are felt.

65. The heart is inclosed externally by a smooth serous membrane called the *pericardium*, which is reflected over the great vessels, and forms a capsule or bag, the internal surfaces of which are kept constantly moist and slippery by a fluid exhaled from them. The method in which the pericardium is doubled on itself so as to bring its two internal surfaces in contact, may be illustrated by pushing the fist into a partially inflated bladder, so that the inner surface of one half the bladder may be doubled against that of the other half, the hand being in contact only with half the outer surface. This will be more clearly comprehended by reference to fig. 8.

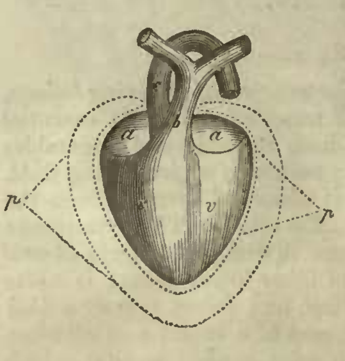


Fig. 8.—DIAGRAM OF THE PERICARDIUM.—*a*, *a*, auricles; *v*, *v*, ventricles; *p p*, pericardium.

66. The heart itself is described by anatomists as a powerful, hollow, and very peculiarly constructed muscle, or rather a combination of muscles, the fibres of which are intricately interwoven with each other. It is divided in the direction of its length by a strong vertical partition which completely separates it into two halves, which have no communication with each other. Another partition, placed crosswise, separates the two upper portions, or auricles, from the two lower, or ventricles, but is perforated by orifices through which the auricle and ventricle of the same side communicate with each other.

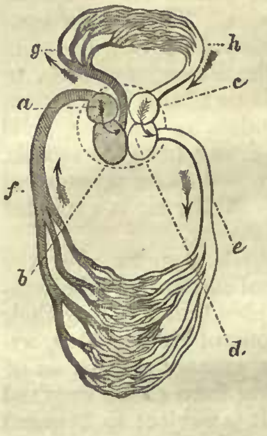


Fig. 9.—CIRCULATION IN MAN.—*a*, right auricle; *b*, right ventricle; *c*. left auricle; *d*, left ventricle; *e*, aorta; *f*, vena cava; *g*, pulmonary artery; *h*, pulmonary veins.

67. The course through which the blood moves in the human circulation may be briefly described, as follows: Commencing, we will suppose, at the left ventricle of the heart, blood is impelled into the aorta or great artery leading from the heart, and along its successive branches, the *systemic arteries*, through which all the organs of the body, except the finer textures of the lungs, derive all their blood. Through these arteries it is conveyed into the *systemic capillaries*, those minute vessels which lie intermediately between the arteries and veins of every part, and in which the blood is brought most nearly into contact with the very substance of the organs. From these it passes into the *systemic veins*, through the main trunks of which, the *venæ cavæ*, it flows into the right auricle, and thence into the right ventricle of the heart. This completes what is called the *systemic* or *greater circulation*, or systemic or general part of the circulation. From the right ventricle the blood is sent through the *pulmonary artery* into the lungs, where it passes through the branches of that artery to the capillaries of the

§ 60. Describe the construction of the hydra. 61. That of the insect.—What is the dorsal vessel of an insect?—Describe fig. 5. 62. Describe the circulation of fishes—Explain fig. 6. 63. What is the difference between the circulating apparatus of fishes and that of reptiles?

§ 64. What is the difference between the heart of a fish and that of a man?—Where is the human heart situated, and what is its form?—At what part of the chest are the beatings of the heart felt? 65. What is the pericardium?—Describe the method in which it incloses the heart. 66. Describe the heart.—What are the auricles?—What are the ventricles? 67. Describe the course of the blood in the systemic circulation.—What is the name of the great artery leading from the left ventricle?—What are its branches called, and what is their use?—Describe the pulmonic circulation.—Explain fig. 9.

PLATE I.

COMPARATIVE VIEW OF THE ORGANS OF CIRCULATION.

FIGURE 1.——CIRCULATION IN THE INSECT.

a, The dorsal vessel, divided into valvular partitions, by the successive contraction of which, the blood is propelled forward.

b, b, Canals which carry the blood to the head.

c, c, Canals passing backward for the supply of the body, and returning the blood to the posterior end of the dorsal vessel.—The course of the circulation is indicated by the direction of the arrows.

FIGURE 2.——CIRCULATING APPARATUS OF THE LOBSTER.

In the lobster and crab, the heart has but a single cavity, and the veins are indistinct, consisting merely of irregular channels excavated in the tissues.

a, The heart; *b, c,* Arteries which go to the head and to the *antennæ* or feelers; *d,* The hepatic artery, or artery of the liver; *e, f,* Arteries which supply the thorax and abdomen.

After the blood has been propelled through these arteries by the heart, it passes into the great vein, *g, g,* from all parts of the body. Thence it passes to the gills, *h,* where it is exposed to the action of the air, and is then returned to the heart by the branchial veins, *i,* which correspond to the pulmonary veins of Man.

FIGURE 3.——CIRCULATING APPARATUS OF FISH.

a, The auricle, having a single cavity, to which the blood is sent from all parts of the body.

b, The ventricle, which receives the blood from the auricle, and propels it through the arterial bulb, *c,* into the branchial artery, *d.* The branchial artery is sub-divided into the arteries of the gills, *e,* in which the blood is aerated.

f, f, The dorsal artery, or aorta, which receives the aerated blood from the gills, and distributes it to all parts of the body.

g, The vena cava, or great hollow vein, which conveys the blood back again to the auricle. *h,* Vena portæ, that branch of the vena cava which conveys the blood from the abdominal organs. *i,* The intestine. *k,* The kidneys.

FIGURE 4.——CIRCULATING APPARATUS OF LIZARD.

a, Left auricle. *b,* Right auricle.—One of these receives the venous blood from the system, and the other receives the arterialized blood from the lungs.

c, The single ventricle, which receives the blood from both auricles, and transmits it partly into the lungs and partly into the aorta.

d, d, Arches of the aorta. *e,* Carotid artery, which distributes the blood to the head.

f, Pulmonary vein, which conveys the blood from the lungs to the heart.

g, Brachial artery, which goes to the fore-legs.

h, h, Pulmonary artery, in which the blood is submitted to the influence of air in the lungs.

i, The lungs. *j,* The stomach. *k,* Vena portæ. *l,* Intestines. *m,* Ventral aorta, or that portion of the aorta contained in the abdomen. *n,* Kidneys. *o,* Liver and vena portæ. *p,* Inferior vena cava, which conveys the blood from all the lower parts of the body to the heart. *q,* Superior vena cava, through which the blood of the upper parts of the body is sent to the heart.

FIGURE 5.——GENERAL VIEW OF THE CIRCULATING APPARATUS OF MAN.

The course and relative positions of the principal arteries and veins of the systemic circulation, are shown in this figure. The pulmonary circulation is illustrated in Pl. 2 and 3. The arteries commence from the great arterial trunk called the aorta, and their branches are distributed to all parts of the system. The venous branches, which accompany the arteries, unite into two great veins, the superior and inferior vena cava, which convey the blood back to the heart.

a, The left ventricle of the heart. *b,* The right auricle. *c,* The superior vena cava. *d,* The root of the pulmonary artery. *e, e,* The aorta, which is seen arching backward over the heart, and passing downward into the abdomen, where it divides into its two great branches, the iliac arteries, through which the blood passes to the lower extremities. *f,* The inferior vena cava, which accompanies the descending aorta and its branches, and returns the blood from the lower extremities.

PRINCIPAL DIVISIONS OF THE AORTA AND VENA CAVA.

It should be remembered that most of the branches which spring from the great artery and vein, are double—that is, each right branch has a corresponding one at the left side—so that there are, for instance, the right and the left carotid arteries, the right and the left jugular veins, &c.

From the arch of the aorta are sent off those arteries which are distributed to the head and arms. The principal ones among these are named as follows:

f, The carotid artery, which ascends in the side of the neck, and divides into the temporal artery, *g,* which is distributed in the temple, and the facial artery, *h,* which supplies the face; and also sends a branch, called the internal carotid, to the parts within the skull.

i, The sub-clavian artery, lying beneath the clavicle or collar-bone. That part of the continuation of this artery which passes through the axilla or arm-pit, is called the axillary artery, *j;* that which lies in the upper arm, the brachial artery, *k;* and in the fore-arm, it divides into the radial and ulnar arteries, *l, m,* which are distributed to the hand and fingers in the manner indicated in the figure.

The principal branches of the descending aorta are named as follows:

The iliac artery, *n,* which, on passing into the thigh, becomes the femoral artery, *o,* and in the leg divides into the tibial and peroneal arteries, *p, q,* which form numerous branches for the supply of the leg and foot.

Before dividing into the iliac arteries, the descending aorta gives off several important branches; as the cœliac artery, from which the stomach and liver are supplied; the renal artery, which goes to the kidneys, and the mesenteric artery, to the intestines; besides many other sub-divisions in various parts of its course.

The branches of the vena cava generally accompany those of the aorta in their distribution, as shown in the figure, and are often called by the same names. The principal divisions of the ascending vena cava are:—The jugular vein, *r,* which accompanies the carotid artery. The sub-clavian vein, *s,* which accompanies the artery of the same name, and receives the blood from the arm and hand.

The inferior vena cava, like the aorta, divides into two great branches, the iliac veins, *t,* the sub-divisions of which accompany those of the arteries, and are called by the same names.

PRINCIPLES OF PHYSIOLOGY. CIRCULATION.

Fig. 1.

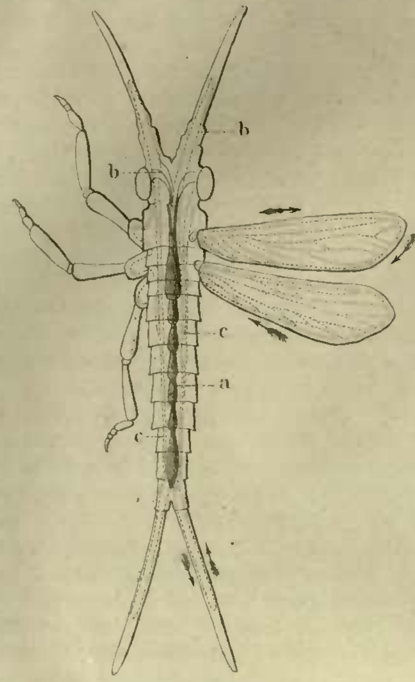


Fig. 5.

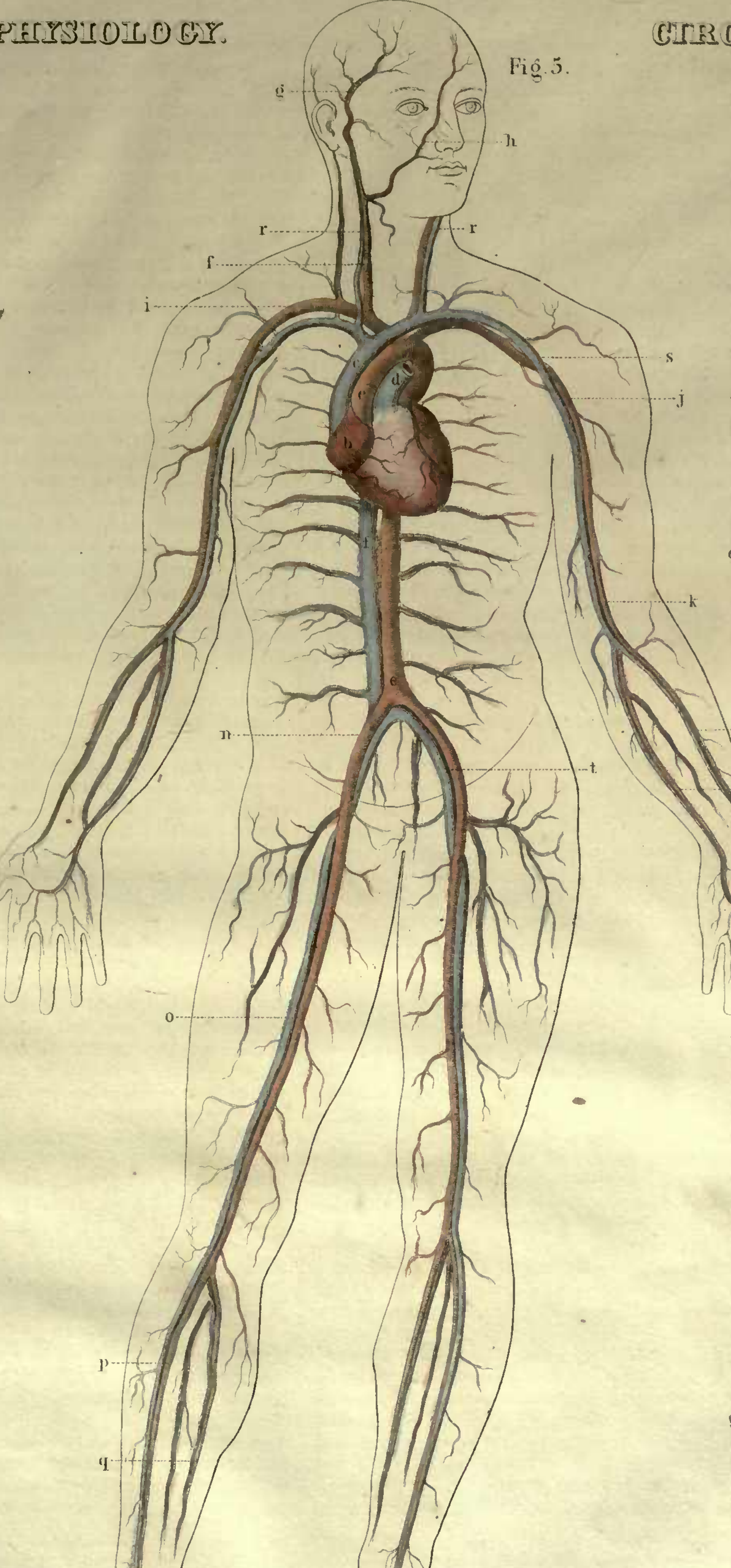


Fig. 2.

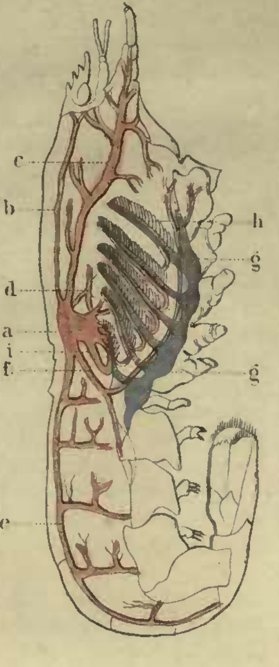


Fig. 4.

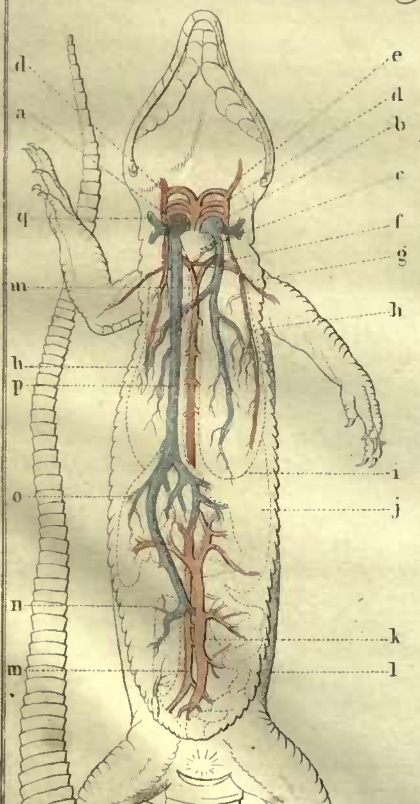
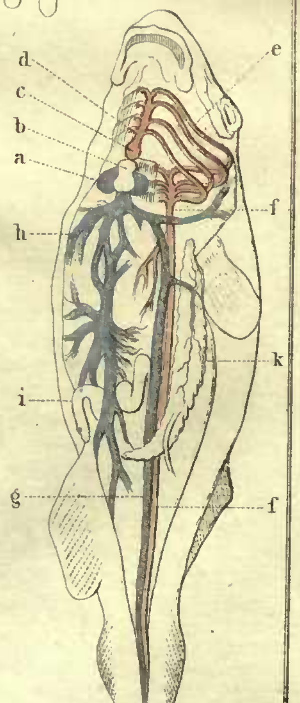


Fig. 3.



Lith of Kellogg.

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Hartford, Conn.

lungs, in which it is exposed to the action of the air. From the pulmonary capillaries the blood enters, in converging streams, the pulmonary veins, which carry it to the left auricle, whence, after having thus completed the lesser or *pulmonary circulation*, it passes again into the left ventricle, whence, in the case here supposed, it started on its course. The human circulation is illustrated by fig. 9.

68. The blood in the left ventricle is pure or arterial blood; that is, it is charged with oxygen in greater proportion than with carbonic acid, and it also contains materials for the supply of the organs. So it remains in all the systemic arteries; but when it reaches the systemic capillaries, it parts with portions of those materials, and its oxygen is, in great measure, consumed by uniting with other substances which enter the blood-vessels from the refuse matter of the tissues. The blood thus becomes impure or venous, and in this state it passes through the systemic veins, the right side of the heart, and the pulmonary arteries; but while in these arteries, by the action of the air in the lungs, it emits carbonic acid and water, and absorbs oxygen, again becomes purified or arterial, and so passes to the left ventricle.

69. A subordinate kind of circulation is inserted in the liver, and is called the *portal circulation*. The veins belonging to the organs of digestion, form a common trunk, the *vena portæ*, which, instead of joining at once with the other trunks of the systemic veins, enters the substance of the liver. There the vena portæ, branching like an artery, carries its share of the blood into capillaries, through which it passes into the hepatic veins (veins of the liver), and then goes through the largest branches of these veins into the vena cava inferior, one of the two main trunks of the systemic venous system, where the portal circulation terminates by mingling its blood with that of the vena cava, which has nearly reached the end of the systemic circulation.

70. The two halves of the heart are similar to each other, except that the walls of the left side are thicker and stronger than those of the right, and the capacity of the left cavities is therefore less than that of the right. The design of the difference in the thickness of the walls would seem to be this: the right ventricle sends its contents only to the lungs, in immediate proximity to itself, and therefore does not require the same power of contraction and dilatation as the left ventricle, which propels the blood to all parts of the system. The walls of the auricles, also, are much thinner than those of the ventricles, and instead of being firm and muscular, like the latter, are yielding and flabby. The reason is obvious: the auricles perform only the office of receiving the blood from the vessels, and transmitting it to the ventricles, while the ventricles, as already mentioned, constitute the propelling organ.

71. The structure and office of the valvular apparatus of the heart are exceedingly important and interesting. Between the right auricle and ventricle are three triangular folds of membrane, called *tricuspid valves*, which open freely into the ventricle, but close perfectly when it is filled. A set of little muscular cords are attached at one end to the edges of the valve, and at the other to the walls of the ventricle, and prevent the valves from being forced up into the auricle by the pressure of the blood during the contraction of the ventricle. This pressure itself holds them together, and they prevent a drop of blood from passing back again from the ventricle into the auricle. Behind the tricuspid valve, leading upward, is the orifice of the pulmonary artery, through which the blood is sent to the lungs.

72. The *mitral* valves, between the left auricle and ventricle, receive their name from a fancied resemblance in shape to a bishop's mitre. Their structure and mode of operation are similar to those of the tricuspid valves.

73. There are also three valves to guard the entrance of the aorta, in the left ventricle, and three similar ones belonging to the pulmonary artery, in the right ventricle. These six valves are named *semilunar*, from the half-moon shape of their folds of membrane. They are attached to the walls of the artery at its exit from the ventricle. The semilunar valves sometimes become ossified, so as not to close together perfectly. In this case they permit a part of the blood to flow back or *regurgitate* into the ventricle, by which the circulation is materially disturbed, and sudden death is occasionally the consequence. A section of one side of the heart, showing the position of the tricuspid valves, and the semilunar valves of the pulmonary artery, is represented in fig. 10. By referring to plate 2, fig. 3, an idea of the direction of the current of the blood through the heart may be obtained. In fig. 10, the right auricle, *a*, receives its blood from the two venæ cavæ, *e*, *e*, and transmits it to the ventricle, *b*, by the orifice, *c*. On each side of this orifice are the membranous folds, which are kept in their places by the tendinous cords, *d*. Now, when the blood is passing from *a* to *b*, these folds yield to the current, but when the cavity, *b*, is filled with blood, and begins to contract, the blood presses against their under sides, and makes them close together, so as to prevent the blood from passing out of the ventricle at any point except into *f*, the pulmonary artery. At the orifice of this artery are situated the semilunar valves, *g*, which open upwards to allow the blood to pass through; but as soon as the ventricle begins to dilate again, so as to give the blood, which has already passed, a tendency to return, the blood presses on the *upper* side of the semilunar valves, which instantly close again, and prevent it flowing back.

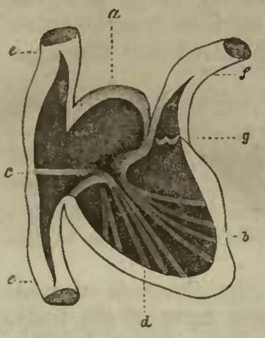

Fig. 10.—SECTION OF RIGHT SIDE OF THE HEART.

74. The average quantity of blood in a healthy man of middle age and size, is estimated at about twenty-eight pounds, and the heart of such a person contracts about seventy-five times in each minute. At each contraction the heart is supposed to empty itself of about two ounces of blood; so that in every three minutes twenty-eight pounds and two ounces of blood pass through the heart, a quantity equal to the entire weight of the blood in the system. How often all the blood of the system actually flows through the heart, we cannot, however, determine with certainty, since the circulation in the immediate vicinity of the heart is performed much sooner than in the remote extremities.

The foregoing calculation is not considered, however, so satisfactory as the results of experiments made by physiologists to ascertain the rapidity with which poisons introduced into the blood are transmitted from one part of the system to another. It is considered nearly certain that such substances move with the blood and at the same rate. Taking this for granted, it would appear, from such experiments, that in man the blood completes its entire circuit in less than a minute.

75. The frequency of the heart's action gradually diminishes from the commencement to the end of life. Thus, during the first year, the average number of pulsations in a minute is from one hundred and thirty to one hundred and fifteen; about the seventh year, ninety to eighty-five; in middle age, seventy-five to seventy; in old age, sixty-five to fifty. In the female, the heart beats more frequently than in the male. The action of the heart is also accelerated or retarded by various circumstances. It is quicker after eating than before; it is slower during sleep than when awake; diseases of different kinds both quicken and retard it; it is slower in the evening than in the morning, and in the sitting than in the standing position.

76. Some of the older physiologists estimated the *force* of the heart's contraction at the enormous amount of sixty pounds. Later investigations have clearly proved that its actual force is only about four and one-quarter pounds, and that this force is sufficient to produce the required result. Dr. Sharpey found that by an artificial force of four pounds and three ounces, water could be propelled through the arteries of a dead body, to the capillaries, and back again through the veins to the heart. Poiseuille, a French physician, by inserting in an artery one end of a bent tube filled with mercury, and allowing the blood to flow into the tube, calculated from the weight of the column of mercury supported by the blood, that the force with which the blood is impelled into the human aorta is about

§ 68. Describe the method in which arterial blood becomes venous.—Describe the change from venous to arterial blood. 69. Describe the portal circulation. 70. What is the difference between the right and left sides of the heart?—Why is the left side stronger than the right?—Why are the auricles thinner and looser than the ventricles? 71. Where are the tricuspid valves?—Describe their structure. 72. Describe the mitral valves? 73. Where are the semilunar valves situated?—Describe them.—What is the use of the valves?—When they become ossified, what is the consequence?—What is represented in fig. 10?—Explain this figure.

§ 74. What is the average quantity of blood in a man?—How often does this quantity pass through the heart?—Judging from the rapidity with which poisons pass from one part of the body to another, how long is the blood in completing its circuit? 75. What is the average number of the pulsations of the heart in the first year of life?—in the seventh year?—in middle age?—in old age?—What circumstances accelerate or retard the heart's action?—76. What is proved to be the actual force of the heart's contraction?—What was Dr. Sharpey's experiment?—what Poiseuille's?—What amount of blood passes through the heart hourly?—what daily?—with what force?

four pounds four ounces, avoirdupois. Other physiologists, by different experiments, have arrived at nearly the same results. Taking, then, the force of the heart at four and one-quarter pounds, and supposing that two ounces of blood are expelled at each contraction of the ventricles, the heart sends forth five hundred and sixty pounds of blood every hour, with a propelling power of about nineteen thousand pounds, or nine and a half tons, or thirteen thousand five hundred pounds daily, with a force of four hundred and fifty-nine thousand pounds.

77. The heart is thus an organ of most untiring energy. It maintains, through the vessels, a perpetual transfer of nutritive fluid from one part of the system to another, furnishing to every organ and tissue the material for its growth and preservation; and it takes away such portions of matter as are no longer of use, thereby securing a constant action and rëaction between the solids and fluids of the body.

78. The arteries, veins, and capillaries, are the channels of communication between the heart and the various parts of the body, through which all these changes take place. Every artery has five coats. The *external* or resisting coat forms a strong, tough investment, which appears principally designed to strengthen the walls of the artery, and to guard against its excessive distension by the force of the heart's action. The *internal* arterial coat consists of a very thin and brittle membrane, which possesses little elasticity, and is thrown into folds or wrinkles, when the artery contracts. The internal surface of this coat, which is next to the blood, is lined with a delicate layer of *epithelium,* which forms a smooth and polished surface, along which the blood may flow with the smallest possible amount of resistance from friction. The *elastic* coat lies directly beneath the external coat, and is composed of fibres of yellow elastic tissue. Beneath this last, and between it and the internal coat, lies the *muscular* coat, which is made up of fibres similar to those of the muscles.

79. The external coat gives to the artery its power of resistance to the force of the heart. The elastic coat equalizes the flow of the blood through the vessels. If the heart impelled the blood through an inelastic canal, like a tube of metal or glass, then, at each impulse of the heart, a quantity of blood must be ejected with a jerk from the other end of the tube, and, during the intervals between the contractions of the ventricles, it would cease to flow. To prevent this is the object of the elastic coat. When the ventricle contracts and forces its two ounces of blood into the artery, the latter yields to the increased pressure, and is distended. As soon as the ventricle ceases to act, the elasticity of the arterial coat causes the vessel to contract again, and resume its former calibre, the force of its contraction being employed in continuing the propulsion of the ventricle. The elasticity of the arteries also enables them to adapt themselves to all the different movements of the body.

80. There is, besides, a contractile power in arteries, distinct from their elasticity. This is considered to be identical with the contractility of the muscles. When an artery is cut or torn off, the divided ends soon contract, so as sometimes to close it perfectly. This contraction may be increased by the application of cold or of stimulating substances, or by simply pricking or irritating the cut ends of the artery. Fatal hæmorrhage is thus often prevented.

81. The jetting movement of the blood, at each successive contraction of the ventricle, being propagated through the artery, is the cause of the *pulse* felt by placing the finger on an artery. It is produced by the elongation and dilatation of the part under the finger, occasioned by the increased pressure upon its walls at the moment when the heart's contraction forces an additional quantity of blood through the aorta and its branches.

82. There is an interesting peculiarity in the distribution of the arteries, by which circulation is provided for in case of an obstruction of any considerable trunk. The branches given off at different points have frequent communications or *anastomoses* with each other, so that the blood may pass from the upper to the lower part of a large artery, by means of these lateral canals, even when its passage through the main trunk is completely prevented. These anastomoses are very numerous in the arteries of the limbs, and particularly about the joints.

83. Where a particular organ requires a large amount of blood, and yet may be injured by too rapid a supply, as in the case of the brain, there is a provision for the purpose. Thus, in grazing animals, as the horse, whose heads are held near the ground in feeding, the arteries which supply the brain suddenly divide, as they enter the skull, into a great number of branches, forming a complex network of anastomosing vessels, which again unite into trunks as before. The effect of these numerous divisions is, to produce a slow and equable flow of the blood, which would otherwise rush with force through the main trunks, every time the head was brought lower than the heart. In man, the blood is prevented from being too rapidly impelled to the brain, by the firmness of the bony canals through which the arteries enter the cranium, and their tortuous course. This will be seen, by reference to plate 2, fig. 4.

84. In the whale, and some other diving animals which breathe air, the vessels under the ribs, springing from the aorta, are enormously dilated, and twisted into a thousand convolutions; thus forming reservoirs of arterial blood by which the capillary vessels are supplied, while the animal is under water. The corresponding veins of such animals are also capable of great distention. Were it not for these peculiarities, their circulation would cease with their breathing, during their long stay beneath the water.

85. In tracing the arteries toward their extremities, we find them gradually diminishing in size, and finally terminating in a series of vessels by which the blood is transmitted from them to the veins. These vessels are called *capillaries,* or hair-like vessels. They are so small as to require a microscope for their examination, their most common diameter in man being about 1-3000th of an inch. They are intimately interwoven with all the tissues, and are so minutely distributed as to render it impossible to puncture any part of the body without wounding some of their delicate divisions. Their office is to bring the blood so near the active elements of the tissues that some of its fluid part may be imbibed by them. They thus serve the important purpose of a medium through which the essential functions of nutrition, growth, and secretion, are accomplished. In them the arterial blood parts with those properties by which it affords nourishment to the organs, and, becoming venous, is transmitted through them to the veins, which carry it back again to the heart. The motion of the blood in the capillaries may be seen, with a microscope, in the web of a frog's foot, or any other transparent part of a living animal. Fig. 11 shows a magnified representation of these vessels in the foot of a frog. Plate 2, fig. 5, displays their arrangement in the human intestine. It is to the contraction of these vessels that the paleness observed in the face, during the effects of fear, is owing, and it is their dilatation which produces blushing. In the first case, the blood is withdrawn from them; and in the second, it is driven more forcibly into them, by the action of the heart.

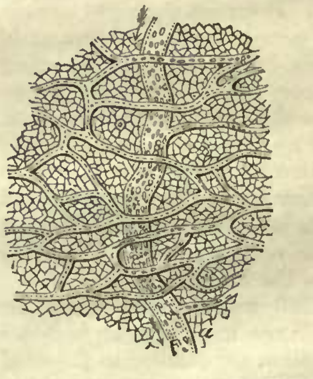
Fig. 11.—CAPILLARIES IN FROG'S FOOT MAGNIFIED.

86. The structure of the *veins* does not differ essentially from that of the arteries. Their contractile power is, however, less, since they possess no complete elastic coat. They are larger and more numerous than the arteries; their collective capacity is greater, and the velocity of the blood in them is consequently less. The limbs are furnished with two sets of veins; one set lying directly beneath the skin, the other deep-seated and accompanying the arteries. When the muscles are exercised, the blood in the superficial veins is made to flow with greater rapidity.

The office of the veins is to carry back the blood to the heart, after it has passed through the arteries and capillaries. Their chief influence in the circulation is effected by means of the valves with which they are abundantly furnished, particularly at points where they are sub-

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§ 77. What is said of the energy of the heart? 78. How many coats have the arteries? —Describe them. 79. What is the use of the external coat?—What of the elastic coat?—What would be the effect, if the blood were impelled through an inelastic tube?—Describe the operation of the elastic coat. 80. Describe the contractile power of the arteries. 81. What is the cause of the pulse? 82. How is circulation effected in case of the obstruction of an artery?

§ 83. What is the peculiar arrangement of the arteries of the head?—What is the effect of this arrangement? 84. How is the circulation of the whale maintained when under water? 85. How do the arteries terminate?—Describe the capillaries.—What is their office?—What does fig. 11 represent?—How are paleness and blushing produced? 86. What is said of the structure of the veins?—How is the existence of their valves easily shown?

PLATE II.

ORGANS OF CIRCULATION.—HEART AND LUNGS.

FIGURE 1.—FRONT VIEW OF HEART AND LUNGS.

Both organs are stripped of their envelopes, the pleuræ and pericardium. The right lung is drawn aside, so as to uncover the heart and large vessels. The left lung is deeply dissected, to show the distribution and mode of ramification of the air-tubes and blood-vessels.

a, The larynx. *b*, The trachea.—The right lung is somewhat shorter than the left, and is divided into three lobes, *c*, *d*, e, while the left lung has but two lobes, *f*, *g*. The surface of the lobes is sub-divided into lobules, by the intersection of great numbers of depressed lines. *h*, Right auricle of the heart. *i*, Right ventricle. *j*, Left auricle. *k*, Left ventricle. *l*, The aorta. *m*, The pulmonary artery. *n*, Left pulmonary veins.—These veins are four in number, two for each lung; and they return to the heart the blood which has been conveyed into the lungs by the pulmonary artery. The division of the pulmonary artery into right and left branches, cannot be seen in this figure, being hidden by the aorta. *o*, The superior vena cava. *p*, Root of the right innominate artery, springing from the arch of the aorta. *q*, Root of the left sub-clavian artery. *r*, Root of the left carotid artery.

FIGURE 2.—BACK VIEW OF THE HEART AND LUNGS.

a, Larynx. *b*, Trachea. *c*, Right bronchus. *d*, Left bronchus. *e*, Left auricle of the heart. *f*. Left ventricle. *g*, Right pulmonary veins. *h*, Left pulmonary veins. *i*, Left pulmonary artery. *j*, Section of the aorta. *k*, Trunks of the brachio-cephalic veins (those which belong to the arms and head). *l*, The opening of the inferior vena cava.—The sub-divisions of the pulmonary arteries and veins, and of the air-tubes or bronchi, are seen accompanying each other in the left lung in both figures.

FIGURE 3.—AN OUTLINE SECTION OF THE HEART;

Showing its cavities and the course of the blood through it. The figure and explanation from Wilson's Anatomy.

a, The right auricle. *b*, The entrance of the superior vena cava. *c*, The entrance of the inferior vena cava. *d*, Opening of the coronary vein, partly closed by its valve. e, The auriculo-ventricular opening (from the right auricle into the right ventricle). *f*, The cavity of the right ventricle. *g*, The tricuspid valve, attached by tendinous cords to the walls of the ventricle. *h*, The pulmonary artery, guarded at its commencement by three semi-lunar valves. *i*, The right pulmonary artery, passing beneath the arch and behind the ascending aorta. *j*, The left pulmonary artery, crossing in front of the descending aorta.—The arrows mark the course of the venous blood through the right side of the heart. Entering the right auricle by the superior and inferior venæ cavæ, it passes through the auriculo-ventricular opening into the ventricle, and thence through the pulmonary artery to the lungs. *k*, The left auricle. *l*, The openings of the four pulmonary veins. *m*, The auriculo-ventricular opening. *n*, The left ventricle. *o*, The mitral valve, attached by its tendinous cords to fleshy columns which project from the walls of the ventricle. *p*, The commencement and course of the aorta behind the pulmonary artery, marked by an arrow.—The entrance of the vessel is guarded by three semi-lunar valves. *q*, The arch of the aorta.—The comparative thickness of the two ventricles is shown in the diagram. The course of the pure blood through the left side of the heart is marked by arrows. The blood is brought from the lungs by the four pulmonary veins into the left auricle, and passes through the auriculo-ventricular opening into the left ventricle, whence it is conveyed by the aorta to every part of the body.

FIGURE 4.—ARTERIES OF THE HEAD.

This figure is intended to show the tortuous disposition of the arteries, after they have entered the skull. It also shows some of the venous sinuses of the head, which are canals lying between the dura-mater (*see* Chapter IX.) and the bone, into which the blood is poured by the veins of the brain. The inside of the base of the skull is represented, the upper portion being removed as far as the orbit of the eye.

a, Vertebral arteries, uniting at *b* into a single vessel, called the basilar artery, which divides in the form of a T, at c, and gives off several branches. *d*, The internal carotid arteries, each of which sends a branch of communication to the basilar, and divides into several other branches; one of which, the ophthalmic artery, *e*, is distributed to the eye. The internal carotid and the vertebral artery each makes no less than five successive curves, in order to break the shock of the column of blood.

f The superior longitudinal sinus. *g*, *h*, Right and left lateral sinuses.

FIGURE 5.—THE CAPILLARIES.

This figure represents a highly-magnified view of the arrangement of the capillaries between the branches of the arteries and veins, as displayed in an intestinal villus (§ 161). *a*, Arteries. *b*, Veins.

FIGURES 6, 7, 8.—VIEWS OF THE HEART.

The heart is here represented in a vertical position, instead of being inclined, as it actually is. The figures are half the size of the adult heart.

Figure 6. *Front View of the Heart.*—*a*, Right auricle. *b*, Right ventricle. *c*, Left auricle. *d*, Left ventricle. *e*, Aorta. *f*, Pulmonary artery. *g*, Superior vena cava. *h*, *h*, Coronary arteries and veins, the nutrient vessels of the heart.

Figure 7. *Back View of the Heart.*—The references are the same, except *i*, Orifice of the descending vena cava. *j*, Right pulmonary veins. *k*, Left pulmonary veins.

Figure 8, gives a view of the cavities of the heart, and their septa or partitions. The letters have the same references as in figures 6 and 7.

FIGURE 9.—PLAN OF THE CIRCULATION.

The object of this figure is to give, at a single view, an idea of the entire circulation, both systemic and pulmonary. The arrows mark the course of the blood. The references are the same as in fig. 3. The capillary vessels of the systemic circulation are represented at *s*, *s*, and those of the pulmonary circulation at *t*, *t*.

PRINCIPLES OF PHYSIOLOGY. CIRCULATION.

Fig. 1.

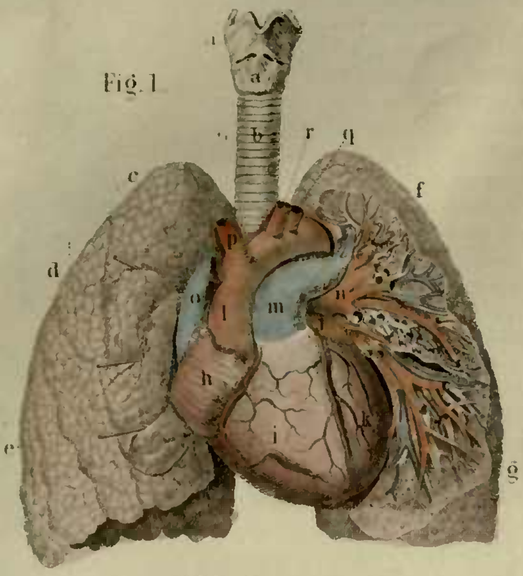


Fig. 5.

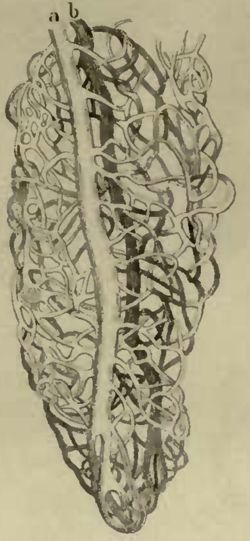


Fig. 2.

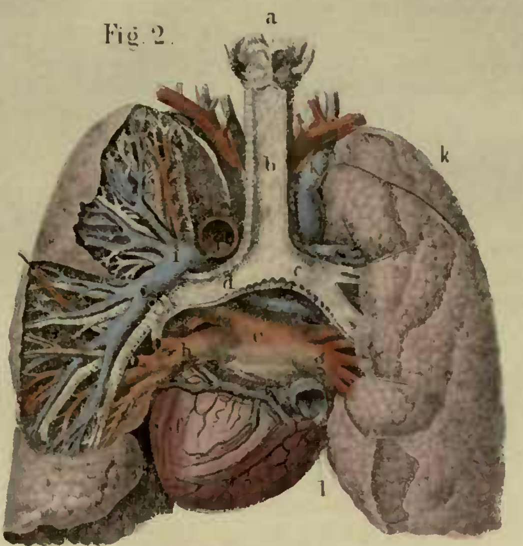


Fig. 6.

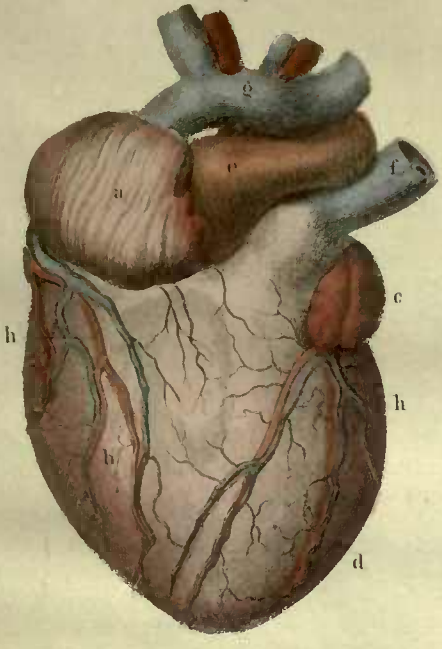


Fig. 8.

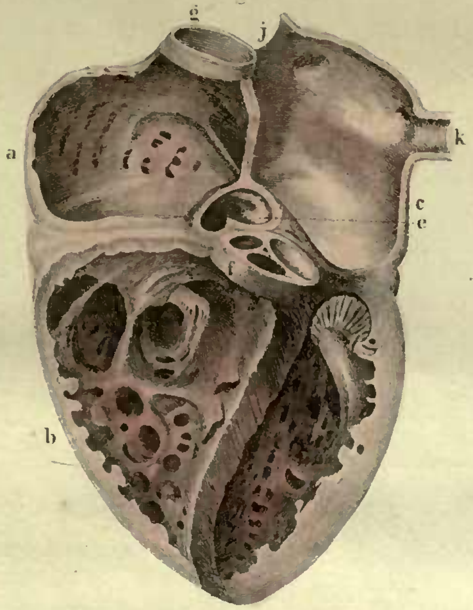


Fig. 7.

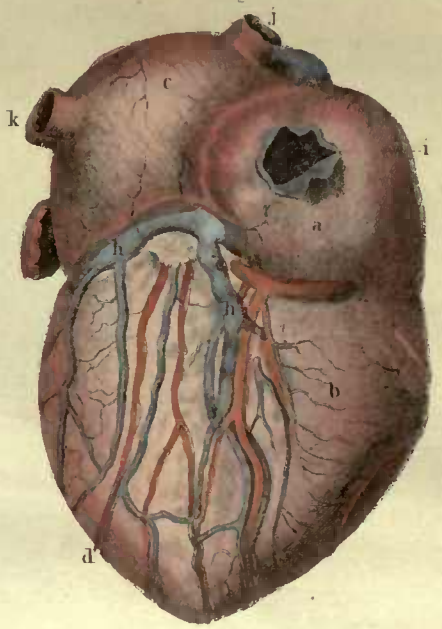


Fig. 4.

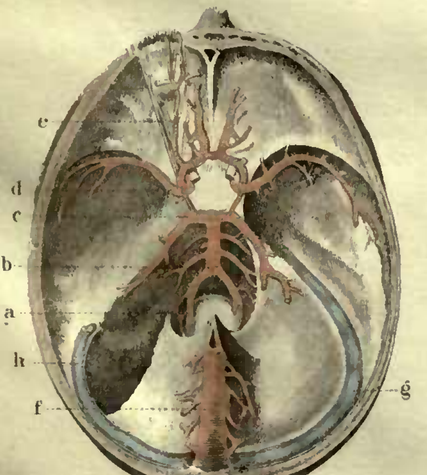


Fig. 9.

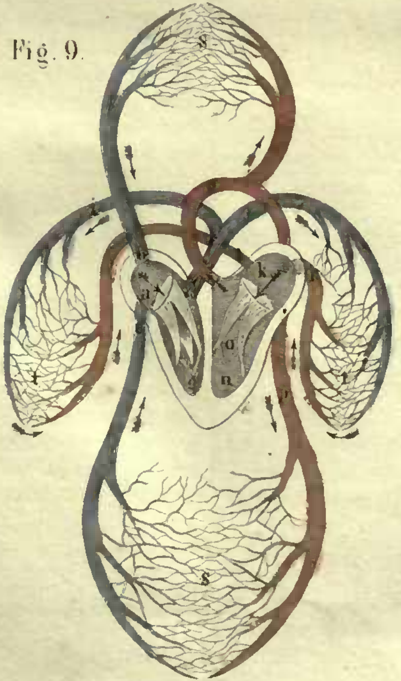
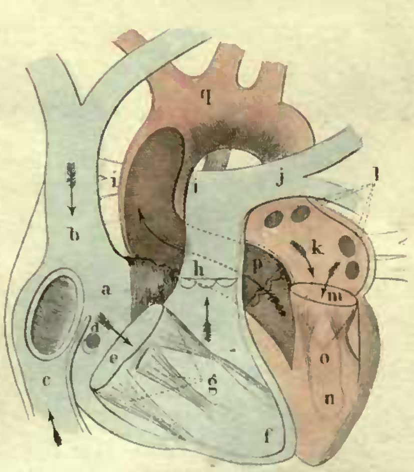


Fig. 3.



Lith of Kellogg. Entered according to Act of Congress, in the year 1850, by Kellogg & Comstock, in the Clerk's Office of the District Court of Connecticut. Hartford Conn.

jected to pressure from the muscles between which they run. These valves are represented in fig. 12. They are similar in construction to the semilunar valves of the arteries already described; but their free margins are turned in an opposite direction, namely, *toward the heart*, so as to stop any backward movement of the blood. While the blood is flowing in its proper direction, they lie close to the sides of the vein; but at the least motion of the blood backward, they close together completely. The existence of these valves is readily demonstrated by pressing a finger on one of the veins of the back of the hand, near the wrist, and drawing it along the vein toward the knuckles. The vein, between the point where the nearest pair of valves is situated, and that where the finger remains, will disappear; since the blood is moved backward in it, and the valves prevent it from being refilled. As soon as the pressure is withdrawn, the blood will be seen to rush to its place again, with great rapidity, and often with a very perceptible shock.

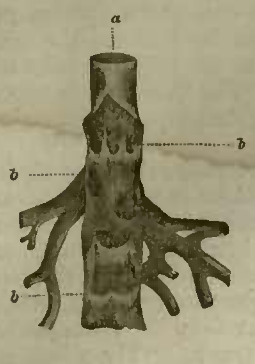


Fig. 12.—VALVES OF A VEIN.—*a*, vein laid open; *b*, *b*, *b*, valves.

CHAPTER IV.

RESPIRATION.

87. RESPIRATION is that function in living bodies by which the circulating fluid is brought under the influence of atmospheric air, during which the fluid exposed to the air, and the air itself, mutually act on each other. Some modification of this function is equally necessary for the maintenance of both animal and vegetable life. The ascending sap of plants cannot be perfected without being exposed to the chemical action of air in their leaves. In animals, the blood, in the capillary circulation, parts with those elements which render it fit for sustaining life; and perpetual renovation of its vital properties, by the purifying influence of the atmosphere, is indispensable to the performance of its functions. In every class of animals, therefore, there is a constant provision made for bringing every portion of their nutritive fluids into contact with air.

88. Now, we find that in plants the process of respiration consists in exposing the sap in the leaves to the action of air. The sap decomposes the carbonic acid which exists in the air, sets free its oxygen, and absorbs its carbon, which is transformed into the various tissues of the plant. In animals, the reverse is the case. A supply of oxygen is necessary to their nutrition, and too great a quantity of carbonic acid is deleterious to them. By means of their respiration, the blood absorbs the oxygen of the air, and sets free its carbonic acid. Thus the two great kingdoms of nature mutually furnish to each other those elements which are necessary for the support of both. Plants purify the air for the use of animals, and maintain in it a supply of that element without which animals cannot exist. Animals, on the other hand, in parting with that which is useless and even deleterious to themselves, furnish the essential element for the growth of all vegetable structures.

89. The organs of respiration are primarily divided into two groups, one of which performs its functions in the air, and the other in the water, and the respiratory apparatus of each group is modified according to these conditions of life. In some of the most simply organized animals, no particular part is exclusively adapted to this function, but it is effected through all those portions of the body which are in contact with the element in which the animal lives, and from which it derives its oxygen. Although this *cutaneous* respiration, as it is called, or breathing through the skin, belongs in its full extent only to some of the lowest orders of animated beings, it is yet worthy of remark, that it exists in some degree in nearly all the higher orders, and even in man. In many of the cold-blooded animals this kind of breathing is of equal importance with that effected by means of the special organs of respiration. For example, the frog will live longer with his mouth and nostrils completely closed, than when his skin is coated with a substance through which the air cannot penetrate. In the lower classes of aquatic animals, the respiratory organs are simply prolongations of the cutaneous covering into fringes, as in the serpula, a kind of marine worm, fig. 13.

Fig. 13.—THE SERPULA.

90. As we ascend in the scale of organization, the respiratory apparatus becomes more perfect and more highly developed, and the animal correspondingly more active. In fishes, respiration is effected by means of a series of arches attached to the head, each of which is supplied with a vast number of thin elongated plates, collectively forming fringes or gills. Each arch is provided with an artery containing blood charged with carbonic acid, branches of which terminate in a capillary net-work on the little fibres which compose the gills. Circulating across these, the blood becomes exposed to the action of the air, and is again collected into another vessel by which it is distributed in the general circulation. The air respired by all animals of this class is obtained from the water in its passage through the plates or gills.

91. In air-breathing animals we also find two different forms of the respiratory organs. It will be recollected that the circulatory apparatus of insects is exceedingly simple, being little else than a pulsating tube. The reason will become obvious, when we consider that in the insect the air circulates through spiral tubes to meet the nutritive fluids, which therefore (as is very evident) does not need a complicated apparatus. The abdomen of an insect is found to be made up of a series of joints, each of which is composed of two plates, one at the upper and one at the lower side. At the edges of each joint, where the two plates meet, there is an opening called the *stigma*, through which the air passes into the body. These little stigmata are found to communicate internally with tubes in which are little spiral threads. These tubes extend through the entire system to the head, antennæ, legs, and even toes; thus carrying air to every part of the animal, and bringing it in contact with the circulating tubes. This arrangement is seen in fig. 14.

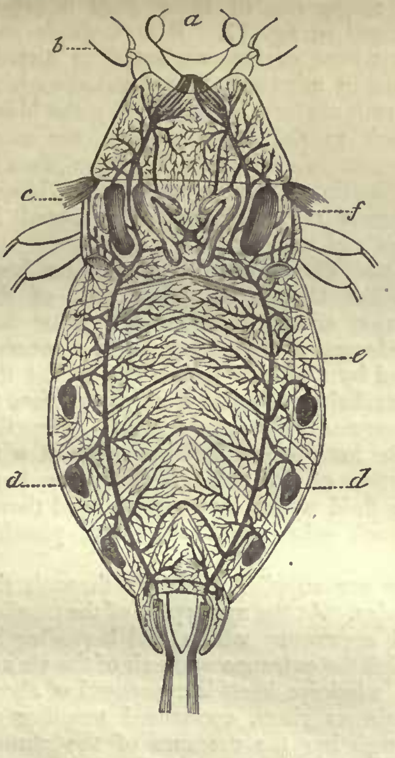


Fig. 14.—RESPIRATORY APPARATUS OF INSECT.—*a*, head; *b*, first pair of legs; *c*, origin of wing; *d*, *d*, stigmata; *e*, air-tubes or tracheæ; *f*, air-sacs.

92. The simplest condition necessary for respiration is, therefore, a membrane supplied with the circulating fluid on one side, and the air on the other. In the various groups of the lower animals, the same principle is so modified as to adapt it to their various modes of life. Thus, in the snail (fig. 15, page 20), which presents the simplest form of a true lung, the organ consists of a respiratory sac, with a blood-vessel branching on its side. In reptiles, we find still another modification of this primitive form. In the frog, for example, the lung consists of two bags, having on their walls small cells on which

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§87. Define respiration.—What is said of the necessity of this function? 88. What is the process of respiration in plants?—What is that process in animals?—How do animals and vegetables then mutually sustain each other? 89. How are the organs of respiration divided?—What is said of the respiration of the lower orders of animals?—What is this respiration called?—What example is given of the importance of cutaneous respiration?—Describe the respiratory organs of the serpula.

§90. How is respiration effected in fishes?—Whence do fishes obtain air to breathe? 91. Describe the respiratory apparatus of an insect.—Explain fig. 14. 92. What is the simplest kind of respiratory apparatus?—Describe the lung of the snail, frog, &c.—Explain fig. 15.—Describe the respiratory apparatus of birds.—What is said of the activity of respiration in birds?—Point out the parts of the ostrich in fig. 16.

the vessels are distributed. In serpents the same condition is found, except that the lung is very long, corresponding to the form of the animal. In birds we find a still higher and more complicated apparatus. The lungs, instead of being simple sacs, are divided into numerous cells. The air passes not only into the lungs, but through them into large sacs along the abdomen, and even into the bones. Respiration in birds is more active than in any other class, and their movements are correspondingly more active. It is not considered certain, however, that the large amount of air contained in the sacs and bones of birds is exclusively designed for the ordinary purposes of respiration. It also serves to give the bird more lightness and buoyancy in its ærial flights. The lungs of the ostrich are shown in fig. 16.

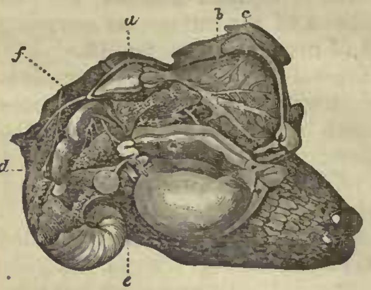


Fig. 15.—Interior of a Snail.—*a*, the heart; *b*, large blood-vessel branching over the sac, *c*; *d*, artery which conveys the blood to the general system; *e*, part of the stomach; *f*, the liver.

93. In man, the lung does not differ in principle from that of the lowest reptile, but it is infinitely more complex. The air cells in the human lung are variously estimated at from 18,000,000 to 600,000,000 in number. A single one of these cells is represented in fig. 17. It is a single sac, on whose surface an artery is distributed in minute capillary vessels which terminate in veins that carry the blood back to the heart. Now, the most perfect lung is nothing more than a collection of these cells, with blood-vessels correspondingly increased in size and number.

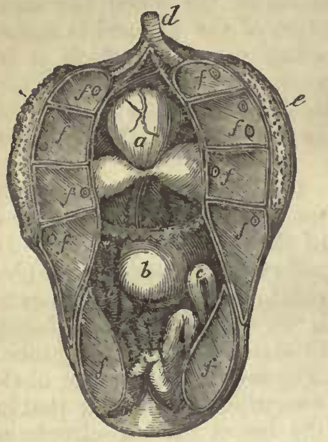


Fig. 16.—Lungs of the Ostrich.—*a*, the heart; *b*, the stomach; *c*, *c*, the intestines; *d*, the trachea or windpipe; *e*, *e*, the lungs; *f*, *f*, *f*, air-cells, in which are also seen the orifices of the tubes through which these air-cells communicate with the lungs.

94. The human lungs are confined to the thorax or upper part of the trunk, which is separated from the abdomen by the diaphragm, a muscular partition. They are covered by a serous membrane called the *pleura*, which also lines the thorax, being reflected from one surface to the other precisely in the same manner as the pericardium. Thus the pleura of the outer surface of the lung is constantly in contact with that which forms the inner surface of the thorax. They are both kept moist by a fluid which they secrete, and therefore glide on each other with the least possible friction.

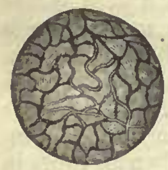


Fig. 17.—Air-cell, with blood-vessels branching over it.

95. The lungs are supplied with air through the *trachea* or *windpipe*. At the upper part of the trachea is a complicated apparatus, which will hereafter be described, by which the entrance and exit of the air are regulated. The windpipe itself is composed of about eighteen cartilaginous rings, connected together so as to form a tube, capable of resisting the pressure of the atmosphere and of maintaining a uniform size. On entering the thorax, the trachea divides into two trunks, called *bronchi*, one of which goes to the right and the other to the left lung. As soon as they enter the lungs, they branch off into numerous divisions and subdivisions, their ultimate extremities terminating in air-cells. In like manner, the pulmonary artery sends minute capillary divisions of itself to each of these air-cells, from each of which there issues a pulmonary vein. The whole substance of the lungs is thus a congeries of air and blood vessels. This arrangement is shown in plate 3, fig. 4. In fig. 18, is shown the trachea, with the larynx at its upper part. The left bronchus penetrates the lung of that side, and the right bronchus is subdivided into its bronchial tubes, the substance of the right lung being removed.

96. The pulmonary arteries bring to each cell a portion of the dark purple venous blood. Carbonic acid and vapor, as before mentioned, are set free from the blood into the cell, and a portion of oxygen is absorbed by it from the air, changing its color to the bright scarlet of the arterial blood. The blood is thus renovated, and fitted for the purposes of sustaining animal life.

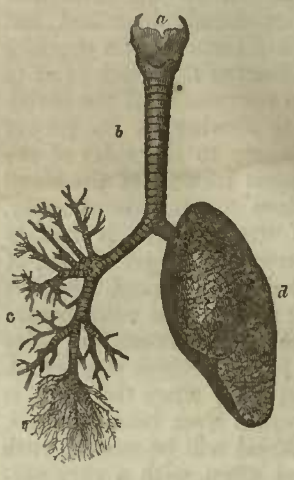


Fig. 18.—*a*, the larynx; *b*, the trachea; *c*, bronchial tubes; *d*, the left lung.

97. The constant renewal of the air in the lungs is provided for in man by a peculiar and simple mechanism. The thorax is a closed cavity, bounded above and at the sides by the ribs, and below by the diaphragm, a great muscular partition which separates the thorax from the abdomen or lower part of the trunk. "The whole of this cavity," to quote the admirable description of Dr. Carpenter, "with the exception of the space occupied by the heart and its large vessels (and also by the gullet, which runs down in front of the spine), is constantly filled up by the lungs. Now, the size of this cavity may be made to vary considerably, in the first place, by the movement of the diaphragm; and in the second, by that of the ribs."

98. "The diaphragm, in a state of rest or relaxation, forms a high arch, which rises into the interior of the chest, as at *a*, fig. 19; but, when it contracts, it becomes much flatter (though always retaining some degree of convexity upward), and thus adds considerably to the capacity of the lower part of the chest. The underside of the diaphragm is in contact with the liver and stomach, which, to a certain degree, rise and fall with it. It is obvious that, when the diaphragm descends, these organs, with the abdominal viscera in general, must be pushed downward; and as there can be no yielding in that direction, the abdomen is made to bulge forward, when the breath is drawn in. On the other hand, when the contraction of the diaphragm ceases, the abdominal muscles press back the contents of the abdomen, force up the liver and stomach against the under side of the diaphragm, and cause it to rise to its former height.

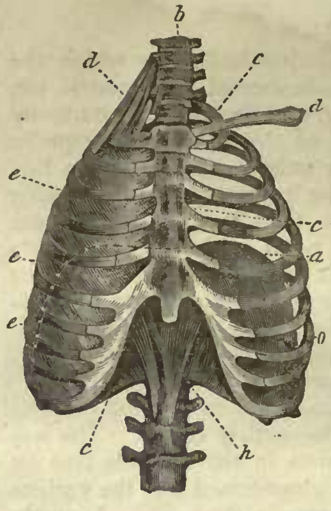


Fig. 19.—Human Thorax.

99. "The play of the ribs is rather more complicated. These bones (to the number of twelve on each side, in man) are attached at one end, by a movable joint, to the spinal column *b*, while at the other they are connected with the sternum or breast-bone, by an elastic cartilage. Now, each rib, in the empty state of the chest, curves downward in a considerable degree; and it may be elevated by a set of muscles, of which the highest, *d*, are attached to the spine and to the first rib, while others, *e*, *e*, *e*, called intercostals, pass from one rib to another. When the breath is drawn in, the first rib is raised by the contraction of the muscle *d*, and all the other ribs, which hang, as it were, from the first, would, of course, be raised to the same degree. But each of them is raised a little more than the one above it, by the contraction of its own intercostal muscle, and thus the lower ribs are raised much more than the upper ones.

100. "Now, by the raising of the ribs, they are brought more nearly into a horizontal line, as are also their cartilages; and as the combined length of ribs and cartilages is the greater the nearer they approach a straight line, it follows that the raising of the ribs must throw them farther out at the sides, and increase the projection of the sternum in front—thus considerably enlarging the capacity of the chest in these directions." This will be more fully understood, by

§ 93. What is the number of cells in the human lung?—Describe one of these cells. 94. Describe the situation of the human lungs.—What is the pleura?—What is the use of the pleura? 95. How are the lungs supplied with air?—Describe the construction of the trachea.—Turn to plate 3, fig. 3, and point out the different parts.—Describe the trachea and its divisions, and the corresponding divisions of the pulmonary artery. 96. What changes does the blood undergo in the lungs?

§ 97. Describe the thorax. 98. Describe the movements of the diaphragm in respiration. 99. Describe the play of the ribs in respiration.—Explain fig. 19. 100. Explain the effect of raising the ribs in increasing the capacity of the chest.—Refer to plate 3, figs, 5, 6.—How do the ribs fall again?—How may this description be better understood?

PLATE III.

ORGANS OF RESPIRATION.

FIGURE 1.—FRONT VIEW OF THE CAVITY OF THE THORAX.

a, b, c, Lobes of the right lung. *d, e,* Lobes of the left lung. *f, f,* The diaphragm, clothed with the pleuræ. *g, g,* Section of the ribs. *h,* Appendage to the breast-bone, called the ensiform cartilage. *i,* The heart, covered by the pericardium, the left lung being drawn aside to display it. *k, k,* Internal jugular veins. *l, l,* Carotid arteries. *m,* Larynx.

FIGURE 2.—POSTERIOR VIEW OF THE CAVITY OF THE THORAX.

a, The larynx, *b,* The trachea. *c, c,* The right and left bronchi. *d,* The aorta. e, The heart. *f, f,* The diaphragm.

FIGURE 3.—THE LARYNX, TRACHEA, AND BRONCHI.

a, The larynx. *b,* The trachea. *c, c,* Bronchi. *d, d, d, e, e, e,* Outlines of the lungs. *f, f, f,* &c., Bronchial tubes.—These tubes continue to ramify, decreasing in size, until they can only be distinguished by the microscope. *g, g, g,* Lymphatic vessels and ganglia.

FIGURE 4.—A PORTION OF THE TISSUE OF THE LUNGS;

Showing the Blood-vessels, Capillaries, and Air-tubes, magnified fifty diameters.

A vein, *a,* is represented ramifying with an artery, *b,* around the intricate air-cells, *c. c.*

FIGURE 5.—LATERAL VIEW OF THE OUTLINES OF THE THORAX AND ABDOMEN.

This figure is intended to show the respective positions of the diaphragm and the walls of the chest and abdomen, in inspiration and expiration. The dotted lines, *a, a,* indicate the contour of the front of the chest and abdomen, when the chest is filled with air after inspiration. *b, b,* The line of the diaphragm, when it is contracted and flattened in inspiration, pressing down the abdominal contents, and causing the abdomen to project. *c, c,* The line of the chest and abdomen, after the air is expired. *d, d,* The arch of the diaphragm, when relaxed in expiration, rising into the interior of the thorax, and drawing inward and downward its point of attachment to the front of the body, e.

FIGURE 6.—FRONT VIEW OF THE OUTLINES OF THE THORAX AND ABDOMEN.

a, a, a, a, Outlines of the thorax and abdomen after expiration. *b, b,* Outline of the diaphragm when relaxed after expiration. *c, c, c, c,* Contour of the chest and abdomen in inspiration. *d, d, d,* Outline of the diaphragm in inspiration.

FIGURE 7.—THE DIAPHRAGM.

This figure shows a sketch of the diaphragm when separated from the body.

a, The right vault of the diaphragm, which is higher than the left vault. *b, b,* The right and left crura or pillars of the diaphragm, by which it is attached to the spinal column.

PRINCIPLES OF PHYSIOLOGY.

ORGANS OF RESPIRATION.

Fig. 1.

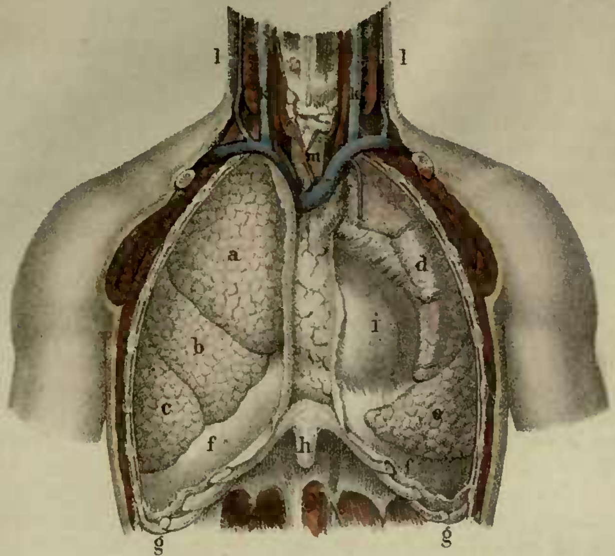


Fig. 2.

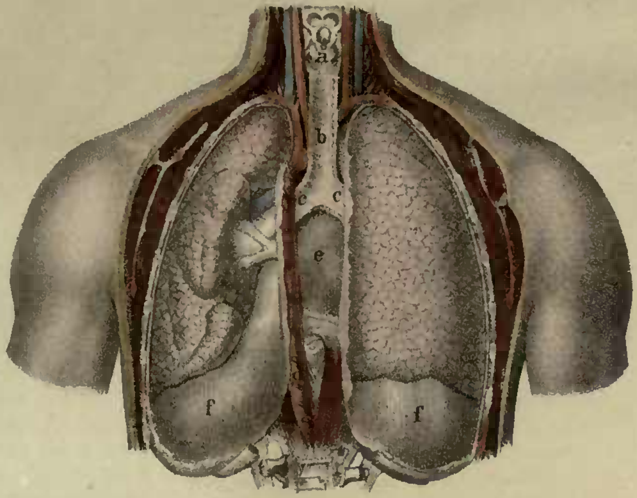


Fig. 3.

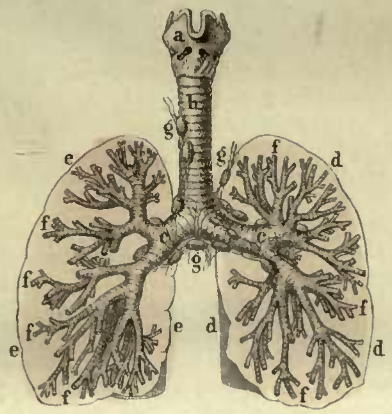


Fig. 4.

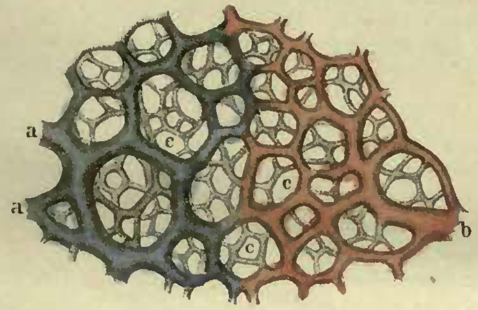


Fig. 7.

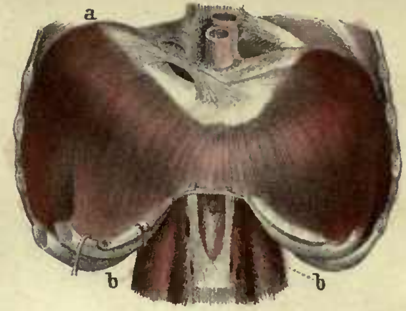


Fig. 5.

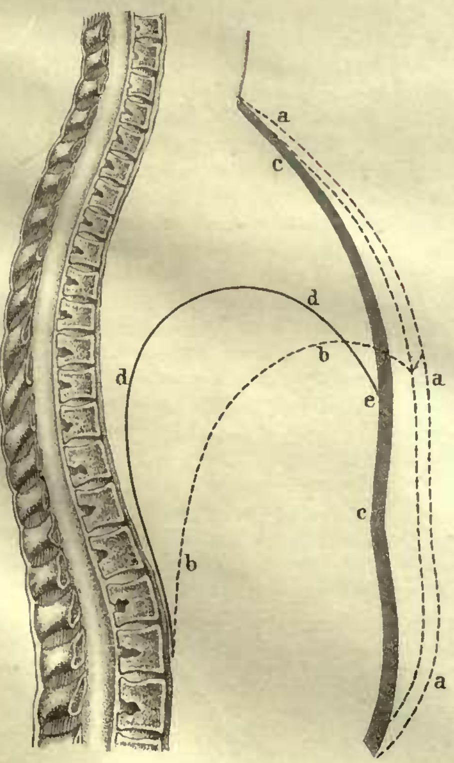
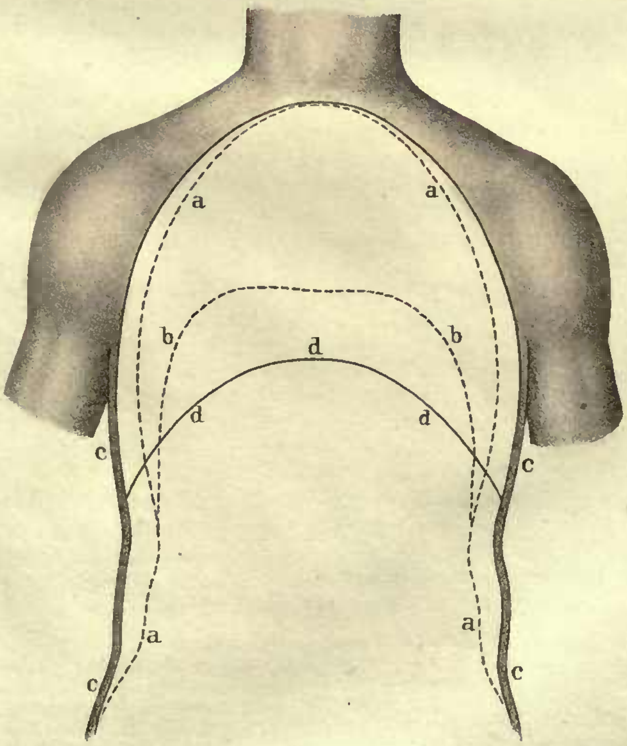


Fig. 6.



Lith of Kellogg
Entered according to Act of Congress, in the year 1850, by Kellogg & Comstock, in the Clerk's Office of the District Court of Connecticut.
Hartford, Conn.

reference to plate 3, figs. 5, 6. When the movement of inspiration is finished, the ribs fall again—partly by their own weight, partly by the elasticity of their cartilages, and partly by the contraction of the abdominal muscles attached to their lower border. For a full understanding of this description, the reader should examine the movements of his own chest, or that of another person, by placing the fingers upon different points of the ribs, and watching their changes of position during the drawing in and the expulsion of the breath.

101. Now, the cavity of the thorax is itself perfectly closed, so that if it were not for the expansion of the lungs, a void or vacuum would be left, when the diaphragm is drawn down and the ribs are elevated. The air around presses in to fill the vacuum, but this it can only do by entering the lungs through the windpipe, and inflating them (or blowing them out), so as to increase their size in proportion to the increase of the space they have to fill. In this manner the lungs are made constantly to fill the cavity of the chest, however great be the increase of the latter.

102. The number of inspirations varies according to the age, the state of the nervous system, and other circumstances. Infants and young persons breathe more rapidly than adults, and a person in a state of mental excitement faster than one in a state of tranquillity. Under ordinary circumstances, the inspirations of an adult are from fourteen to eighteen in a minute. The average quantity of air taken in at each inspiration is supposed to be about twenty cubic inches. Thus, reckoning sixteen inspirations in each minute, about twenty thousand cubic inches of air pass through the lungs in an hour, making two hundred and sixty-six and one-third cubic feet in twenty-four hours. The air which has passed through the lungs contains about one twenty-sixth part of carbonic acid, and thus about ten cubic feet of that gas, containing nearly six ounces of solid carbon, are thrown off in a day. At the same time, about twenty-seven ounces of oxygen are absorbed into the blood. The quantity of watery vapor exhaled from the lungs in twenty-four hours is from six to twenty-seven ounces.

103. Carbonic acid ordinarily exists in the atmosphere, in the proportion of one part in one thousand, and when this proportion is increased to one part in one hundred, its deleterious effects are manifested by head-ache, oppression, languor, and fainting. Now, since a man produces from his lungs about ten cubic feet of carbonic acid in a day, if he were inclosed in a room ten feet square and ten feet high, which would contain one thousand cubic feet of air, he would, in twenty-four hours, communicate to its atmosphere sufficient carbonic acid to raise its proportion to one part in one hundred, provided there is no influx of air from the outside. Of course, this effect is never completely produced in fact, since no chamber is so closely constructed as to prevent some interchange of its air with that of the outside. But the same effect is often produced in a shorter time, in a badly ventilated room, by a collection of a large number of persons.

104. It is evident that if the chamber of ten feet square were to be occupied by twelve persons for two hours, the same effect would be produced as that occasioned by one person in twenty-four hours. The effect, indeed, would be greater, since the quantity of carbon is produced twelve times more rapidly, and the outer air has only one-twelfth part of the time to flow in. If, then, twelve hundred persons remain in a church or assembly-room for two hours, they will produce one thousand cubic feet of carbonic acid in that time. If the building be eighty feet long, fifty broad, and twenty-five high, it will contain one hundred thousand cubic feet of air. And thus an amount of carbonic acid equal to 1-100th part of the whole contents will be diffused through such a building in two hours, if no provision be made for ventilating it. And the injurious effects will be the greater, if there is an additional consumption of oxygen produced by the burning of lights.

105. Hence we see the great importance of providing for free ventilation, wherever large assemblages of persons are collected together, even in buildings of the largest size. The weariness, drowsiness, restlessness, and head-ache, experienced while attending a crowded assembly, may be mostly traced to this cause. In schools, factories, and other places, where a large number of persons remain together during many successive hours, too much attention cannot be paid to the subject of ventilation; especially, since the smaller the room, the greater will be the *proportion* of carbonic acid in its atmosphere, after having been breathed by a number of persons for any given time. In the narrow and ill-arranged dwellings of the poor, lack of ventilation is productive of more sickness than even an insufficient supply of food and clothing, and is especially favorable to the spread of contagious diseases.

106. When we consider the constant and important labor performed by the lungs, their delicate structure, their liability to injury from sudden changes of temperature, from great physical exertion, and from excessive mental excitement, it is hardly a matter of wonder that so many of the human race die of diseases of this organ. One of the most fertile causes of injury to the lungs is neglect of their most important assistant, the *skin*. The skin affords great relief to the lungs, in aiding in the excretion of vapor and other waste matter which pass off in the form of perspiration. If, then, the surface of the skin is allowed to become foul, from lack of cleanliness, its pores become obstructed, and the waste matter which would otherwise be excreted, is thrown back into the blood, and carried to the lungs, which are obliged to undergo more severe labor in throwing it off. If they are not able to do this completely, the noxious particles must remain in the system, the blood must be imperfectly purified, and disease must inevitably be the consequence. The exceeding importance of exciting a healthy action of the skin, by bathing, and regular washing and rubbing, cannot, therefore, be overrated.

107. The lungs are also liable to injury from sudden changes of temperature. If the surface of the body is suddenly chilled, perspiration is checked, the capillary vessels are contracted, and a larger amount of blood than the lungs can properly act upon is thrown into them at once. Hence the necessity of protecting the body by clothing sufficient and proper to prevent its feeling in too great a degree the rapid changes to which our climate is liable. Hence, also, is perceived the impropriety of changing too suddenly, or at too early a season, the warm woolen clothing of winter for the thinner habiliments of the hot season. It is better to be somewhat incommoded by the heat of flannels in the spring, than to run the risk of injury to the lungs by taking off the flannel, as is too often the custom, on the first warm day. A uniform protection against variations of temperature should be, as nearly as possible, adopted. That is, the body should at all times be so clothed that it can endure the sudden changes of each season with impunity.

ANIMAL HEAT.

108. Closely allied with the process of respiration is the power of maintaining animal heat, a certain amount of which is necessary to vital action in all animals. The ability to produce heat, and thereby to resist the influence of cold, varies exceedingly in different orders of animals.

109. Those animals which possess the most perfect development of the respiratory organs are capable of retaining their activity in the coldest extremes of temperature, and of generating heat sufficient to resist the severest climate. In the slug and snail (§ 92), whose respiratory apparatus is exceedingly simple, the temperature is very little above that of the surrounding air. The temperature of fishes (§ 62), which perform their respiration by means of gills, is almost wholly dependent on that of the water, rising or falling with the warmth or cold of the sea, river, or lake, which they inhabit. In reptiles (§ 63), there is a farther development of the lung, and a corresponding increased power of maintaining a uniform temperature. When the warmth of the air is between 44° and 50°, the body of a reptile will be several degrees warmer.

110. In some cold-blooded animals a most remarkable provision exists for preserving life when the temperature of the body is reduced below the freezing point. As the cold increases, the organs become more and more inactive, until at length all the animal functions cease, and torpidity ensues. Some species of insects and fishes may be frozen solid like ice, and yet retain life, and again become active

§ 101. How are the lungs made constantly to fill the cavity of the chest.—Why does the air rush through the wind-pipe? 102. What is said of the number of inspirations?—What calculation is made as to the quantity of air which passes through the lungs?—How much carbonic acid and carbon are exhaled in a day?—How much oxygen is absorbed?—How much watery vapor is exhaled? 103. What is said of carbonic acid and its effects? 104. Repeat what is said of the effects of respiration in a large assembly, &c. 105. What is said of the importance of ventilation.

§ 106. How are the lungs liable to injury?—How does the skin assist the lungs?—What are the consequences of neglect of the skin? 107. What are the consequences of sudden check of perspiration?—What is said of the importance of properly protecting the body against changes of temperature? 108. What is said of the ability of animals to produce heat? 109. In what animals is this ability greatest?—What is said of the temperature of the snail?—of the fish?—of the reptile? 110. What is said of freezing insects and fishes?

when exposed to a proper degree of warmth. The freezing appears to produce no chemical change either in the tissues or the fluids; it merely suspends the operation of their affinities until, by a return of warmth, they are excited to action.

111. In birds and the mammalia, whose nervous and respiratory systems are perfectly developed, an uniformly elevated temperature is sustained. Respiration is more active in birds than in any other class of animals, and their animal heat is consequently greater, ranging from 100° to 112°. In man, at adult age, it may be estimated at from 98° to 100°, and in children as high as 102°. In fevers, the temperature is frequently several degrees higher; in scarlet and typhus fevers as high as 106° or 107°. In health, it is about one degree and a half lower during sleep than when awake. Hence, when asleep, we always require additional clothing.

112. In the young of all animals the temperature is always a few degrees higher than in the adult, and respiration is correspondingly more frequent; but the sensibility to cold is much greater, and the power of resisting it much less. Hence, when young animals are exposed to a low temperature, without proper protection, the animal heat rapidly diminishes; and if artificial heat be not afforded, death ensues.

113. A comparative view of the process of respiration, in connection with the development of animal heat, very clearly shows that the lungs, under the influence of the nervous system, are the organs by which is maintained that degree of warmth necessary to all vital action. Nearly all the blood passes through the lungs in one minute (§ 74), or, at most, in three minutes. The various tissues, together with the food received into the system, supply the blood with a certain quantity of carbon. When the blood reaches the innumerable air-cells in the human lung, and the carbon which it parts with there unites with a portion of the oxygen of the air contained in the cell (§ 96), one hundred and thirty-five degrees of heat are produced by the union of each ounce of carbon.

114. Artificial heat is produced by causing the carbon of the wood or coal to unite with the oxygen of the atmosphere. In the fire, as well as in the lungs, the amount of heat is in direct proportion to the amount of oxygen and carbon combined with each other; and the carbonic acid, which is the product of this combination, is also set free in the same proportion. That is, the quantity of carbonic acid is large or small, according to the amount of the respiration or of the fire.

115. The lungs, however, must not be regarded as the only source of animal heat. For it is probable that some degree of heat is produced by the combining of portions of blood with the tissues; and there is reason to believe that certain chemical changes, resembling that effected in the lungs, are constantly taking place through all the tissues of the body, whereby a small amount of heat may be evolved.

116. Some very interesting phenomena have been observed in certain warm-blooded animals which *hybernate* or spend the winter in a semi-torpid state. One of these hybernating animals, common in New England, is a species of marmot, usually called *woodchuck*. This animal enters his den or burrow about the first of October, closing the entrance after him with hard-packed earth. There he remains until about the first of the next April, most of the time enjoying a very profound sleep, and breathing just often enough to keep himself comfortably warm. During the five months which he remains in this condition, his whole number of respirations does not exceed those of eight or ten days of activity in the summer months.

117. All hybernating animals become enormously fat in the autumn, before they begin their winter's nap. This fat, which contains a very large proportion of carbon, is gradually absorbed and combined with the oxygen in the lungs, in order to maintain the necessary temperature, and the animal comes forth from his hiding-place, in the spring, greatly emaciated, and with a most excellent appetite. During the long period of his sleep, digestion and the other animal functions not necessary to respiration have been entirely suspended; and the small supply of oxygen, indispensable to his diminished respiration, has been obtained from the air which penetrates through the earth to his burrow. These animals possess no peculiarity of structure by which they are particularly suited to this mode of life. They seem rather to have an instinctive impulse to adopt this economical method of passing the winter, because, during that season, their usual supply of food can no longer be obtained. Indeed, some other animals, whose habits do not commonly lead them to hybernate, have the power of prolonging life in a similar manner; and the same species which hybernate in a cold climate will not do so in a warmer one. This habit of sleeping through the winter seems, therefore, by a wise provision of the Creator, to be given to certain animals, in order to supply the failure of all other means of maintaining life.

CHAPTER V.

DIGESTION.

118. Change is the characteristic of life or vital action. No being can be regarded as alive which is not undergoing some change perceptible to the senses. Plants which have ceased to grow, extend, or multiply themselves, are considered as destitute of life. Every animal, however simple its structure, however obscure its movements, must be performing some action, and passing through some change, or it is no longer a living being. Indeed, life, in every form, is but a series of changes, a constant succession of waste and repair, more or less apparent and active, according to the structure and necessities of each individual organism. In the higher order of animals, this phenomenon is too evident to require demonstration. The particles which constitute the body, with its assemblage of organs, become successively inert and useless, and must be thrown off for the reception of others, which, after fulfilling their office, in their turn give place to new particles. In man, these mutations of matter are carried on with an activity and energy truly surprising. It is the object of digestion to prepare the materials for this essential process of vital action.

119. Digestion may, then, be defined as that process by which those parts of food which may be employed in the formation and repair of the tissues, or in the production of heat, are made fit to be absorbed and added to the blood. Plants (§ 15) take up their nutritive elements from the air and earth, in a state already adapted to their use. But all animal organizations require a certain degree of preparation of their aliment, and for this purpose are supplied with organs more or less complex. In the polype (§ 60), a single sac or cavity, in which to dissolve its food, is all that is required. In the higher orders, some mechanical division of the food is necessary in order to prepare it for solution, and, accordingly, instead of the single digestive sac of the polype, they have a cavity (the mouth), provided with a grinding or masticating apparatus (the teeth). Another cavity (the stomach) receives the masticated food from the mouth, and reduces it to a proper state for transmission to a third cavity (the intestines), whence it is taken up and poured into the blood.

MASTICATION.

120. The apparatus for dividing the food mechanically is formed according to the condition of the food which the animal requires, and the rapidity with which the process of dissolving that food is carried on. If the process is to be performed rapidly, the food requires just that preparation which would be made by a chemist wishing to dissolve a given substance in the shortest period of time. He would not throw it into his solution in a single mass, but would divide it into as many portions as possible, in order to expose the largest amount of surface to the action of the dissolving fluid. Thus, in those animals which grind, chew, or masticate their food most perfectly, the process of digestion is performed in a few hours, while in those which swallow their prey whole, as the snake, several days are required for the purpose.

§ 111. What is said of the temperature of birds?—of that of man?—Why do we need more clothing when asleep than when awake? 112. What is said of young animals? 113. By what organs is animal heat principally maintained?—Describe the chemical action by which heat is generated in the lungs. 114. How is artificial heat produced?—How is the amount of heat and of carbonic acid proportioned? 115. What are other sources of animal heat besides the lungs? 116. Describe the hybernation of the woodchuck. 117. What becomes of the fat of hybernating animals?—Whence is their oxygen derived?—What is said as to the reason for the habit of hybernating?

§ 118. What is said of change as essential to life?—What changes take place in the particles of the body?—What is the object of digestion? 119. Define digestion.—How do the digestive organs of the higher orders of animals differ from the single sac of the polype? 120. How is the masticating apparatus formed?—If the food is to be dissolved rapidly, what preparation does it require?—What animals digest most rapidly?—what most slowly?

121. In most of the higher animals, mastication is performed by means of *teeth*, implanted in the jaws, and so arranged as to act against each other, with a cutting, grinding, or crushing power, according to the nature of the food on which they operate. In man, each tooth is originally developed in the interior of a small membranous sac called the *dental capsule*, which is lodged in the jawbone, as seen in fig. 20, which represents half the lower jaw of a very young infant. Inside of this sac, which is abundantly furnished with blood-vessels, is a little bud-like protuberance, *b*, fig. 21, to which are sent numerous minute nerves and vessels, *c*. This little bud is called the *pulp*, and is gradually converted into the *ivory* of the tooth, which, in man, constitutes nearly its whole structure. The ivory begins first to be formed at the highest parts of the capsule, *d, d*. The upper portion or *crown* of the tooth becomes incrusted with *enamel*, the hardest substance found in the human body. The fang or root is covered with a substance closely resembling bone, and called the *cortical* substance.

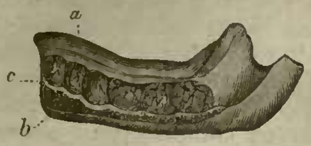


Fig. 20.—Development of Teeth.—*a*, the gum; *b*, the lower jaw; *c*, dental capsules.

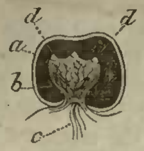


Fig. 21.—Dental Capsule.

122. Finally, the whole of the pulp is changed to ivory, except a small portion in the cavity of the tooth, which retains a small nerve and artery, and is frequently laid open by the decay of the outer wall. It is by the action of the air upon the nerve, in this case, that tooth-ache is usually produced. As the root of the tooth becomes developed, the crown is gradually pushed upward through the gum, or, in common language, the tooth is *cut*. While the tooth is thus becoming developed, the bone of the jaw hardens, closes round the root of the tooth, and forms its socket. When it is once complete, the tooth acquires no further growth, and does not seem to possess the power of repairing injuries occasioned by disease or accident.

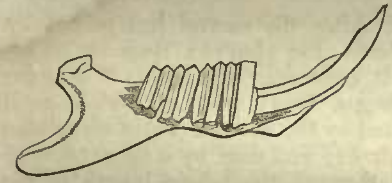


Fig. 22.—Jaw and Teeth of Rabbit.

123. But the teeth of some animals never cease to grow, and their central cavity is always filled with pulp. Additional matter is constantly being formed at their base, and the whole tooth is thus pushed upward. This is the case with the tusks of the elephant, and also with the gnawing teeth of such animals as the rabbit, the squirrel, the rat, and others (fig. 22). Notwithstanding the continual wearing away of these teeth, by contact with hard substances, they are yet kept up to their proper level by their constant growth from below.

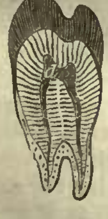


Fig. 23.—Section of a Human Tooth.—*d*, dental cavity.

124. Fig. 23 represents the section of a human tooth as seen under the microscope. The ivory radiates in minute wavy tubes from the centre or pulp-cavity. The enamel forms a crust on the whole surface of the crown of the tooth. It is formed of a multitude of six-sided columns, packed closely against each other, one of their extremities resting upon the ivory, and the other constituting the surface of the tooth.

125. In man, and most of the other mammalia, there are three kinds of teeth, adapted to different purposes. The first have a thin cutting edge, and are intended simply to *divide* the food; these are called *incisor* teeth. Others have a conical form, and—especially in carnivorous animals—project beyond the first. They are called *canine* or dog-teeth, and are not adapted to cut the food, but, by being fixed deeply in it, enable the animal to pull it asunder. The teeth of the third kind are adapted, by means of their flattened surface, to bruise and grind the food, and are called *molar*, or mill-like teeth. The molars are farther divided, according to their number of fangs or roots, into *bicuspid* or small molars, and *grinders*. The different forms of these teeth, as found in the human jaw, are represented in fig. 24.

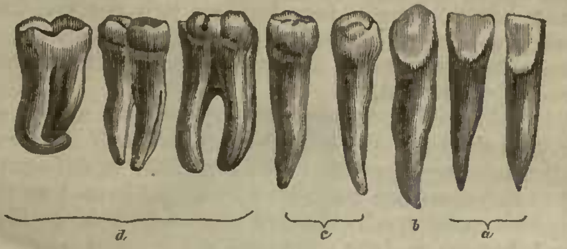


Fig. 24.—Human Teeth.—*a*, incisors; *b*, canine tooth; *c*, bicuspid teeth; *d*, molars.

126. The manner in which these different teeth are implanted in the jaw, is in accordance with their several uses. The incisors, whose action tends rather to force them more deeply into their sockets, than to draw them forth, have but a single root or fang, of no great length. The canine teeth, which are often liable to considerable strain, are much more deeply set into the jaw than the incisors, especially when they are long and large, as in the cat-tribe. The molars, whose action requires great firmness, have two, three, or four spreading roots, which fix them firmly to the jaw, and prevent them from being forced out of their sockets.

127. The correspondence between the arrangement and form of the teeth of any animal, and the nature of the food on which that animal feeds, is so exact, that, by simply inspecting its teeth, the comparative anatomist can usually determine the general structure and habits of the animal to which they belong. Thus, in those which feed entirely on animal flesh, the molar teeth are so compressed as to form cutting edges, which work against each other like a pair of shears (fig. 25). In animals which live on insects, these teeth are raised into conical points, which lock into corresponding depressions in the teeth of the opposite jaw (fig. 26). When the animal lives principally on soft fruits, these teeth are simply raised into rounded elevations (fig. 27); and when they are destined to grind harder vegetable substances, their surface is flat and roughened, as in those of the horse, cow, and elephant. In the latter case, this rough surface is preserved by the arrangement of the enamel, which, instead of covering the crown of the tooth, is disposed in upright plates, the space between which is filled up by ivory. The ivory, being softer than the enamel, is worn down sooner, and thus the plates of enamel are constantly left projecting, so as to form a surface admirably adapted to the grinding action of the tooth. This is shown in fig. 28.

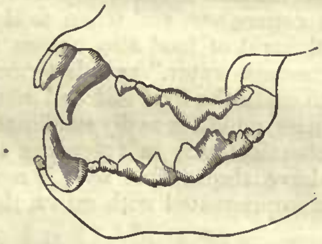


Fig. 25.—Teeth of Carnivorous Animal.

Fig. 26.—Teeth of Insect-eating Animal.

Fig. 27.—Teeth of Frugivorous Animal.

Fig. 28.—Teeth of Herbivorous Animal.

128. In man, the teeth which are first formed are called *milk-teeth*, and are twenty in number—four incisors in the front of each

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§ 121. How is mastication performed?—Describe the development of the teeth in man.—Explain figs. 20 and 21. 122. What farther changes take place in the formation of teeth?—What causes tooth-ache?—Describe the cutting of teeth. 123. Describe the teeth of gnawing animals. 124. Explain fig. 23. 125. What are the three kinds of teeth, and what are their uses?

§ 126. What is said of the manner in which the different kinds of teeth are implanted in the jaw? and why are they so implanted? 127. What is said of the correspondence between the arrangement of the teeth and the structure of the animal?—Describe the teeth of the carnivorous, insectivorous, frugivorous, and herbivorous animals. 128. What are the first human teeth called?—What is their number?—When do they fall out?—What is the number of the permanent teeth?—What is the wisdom-tooth?

jaw, and two canine teeth and four molars on each side. All these teeth fall out at from six to eight years of age, and are gradually replaced by the permanent teeth, which are thirty-two in number, sixteen in each jaw; namely, four incisors, two canines, four bicuspids, and six true molars. The last great grinder does not make its appearance until long after the rest, whence it is called *dens sapientiæ* or *wisdom-tooth.*

129. It is principally by means of the muscles which move the lower jaw, that the teeth are brought into action. The extent and nature of the movements of the lower jaw differ in different animals, according to the operation necessary to be performed on their food. In carnivorous quadrupeds, the jaw has only a hinge-like action, opening and shutting, and the sharpness of the molar teeth render it a powerful cutting instrument. On the other hand, the jaw of a grass-eater, as an ox, or a horse, possesses a great degree of lateral motion, by which the food is ground between the rough surfaces of the teeth. In the gnawing animals, again, as the squirrel, the lower jaw has no power of moving from side to side, but is drawn rapidly backward and forward, and the ridges of the molar teeth being arranged crosswise (fig. 22), they act as a powerful file, by which the hardest nutshell is quickly rasped into pulp.

130. Since no particular class of substances forms the entire food of man, that is to say, since he does not exclusively eat flesh, like the tiger, nor vegetables, like the ox, we may naturally look for a combination of these different modes of action in his jaw. We find, accordingly, that the jaw of man possesses a moderate degree of motion upward and downward, from side to side, and forward and backward; thus being adapted to the mastication of all the endless variety of articles upon which the teeth are called to operate. As the principal force is required in shutting the jaw, the muscles employed for this purpose are large and powerful. They are attached to the skull in the region of the temple, where their action may be observed during mastication, and whence they are called temporal muscles.

INSALIVATION.

131. The act of insalivation, or the blending of saliva with the food, during mastication, is of great importance in preparing for digestion. The saliva is secreted in three pairs of glands, through canals leading from which it is poured into the mouth. Two pairs of these are situated beneath the tongue, and are called the *sub-lingual* and *sub-maxillary* glands. Another larger pair, the *parotid* glands, are situated, one at each side, in the cheek, just below the ear. The quantity of saliva secreted is subject to great variation. When the tongue and masticating muscles are at rest, only enough saliva is secreted to keep the mouth moist. But the flow is much accelerated when the movements of mastication commence, and when food is taken into the mouth. The sight or thought of food also causes an increased flow of saliva, making the "mouth water," as it is termed.

132. The purpose of the saliva is to make the food soft and moist, so that it may be reduced to a pulpy mass, which is easily swallowed. It is also supposed to perform some chemical part in preparing the food for digestion, since experiments have shown that food is more readily acted on by the stomach, when impregnated with saliva, than when moistened by water.

133. "If the preliminary operations of mastication and insalivation be not thoroughly performed, the stomach has to do the work of preparation, as well as to accomplish digestion. Thus it becomes over-worked, and manifests its fatigue by not being able to discharge its own proper duty. Thus the digestive function is seriously impaired, and the general health becomes deranged in consequence. A malady of this kind is very prevalent in the United States, and is almost universally attributed by medical men—in part, at least—to the general habit of very rapid eating, or rather *bolting*, the meals. There is another evil attendant on this practice. Much more food is swallowed than is necessary to supply the wants of the system; for the sense of hunger is not so readily abated by food which has not been prepared for digestion; and thus the feeling of satiety is not produced until the stomach has already received a larger supply than it is well able to dispose of."

DEGLUTITION.

134. When mastication is completed, the food is transmitted in successive portions to the stomach, by the act of *deglutition* or *swallowing*. The food being collected at the back part of the tongue into a ball or bolus, is pressed against a sort of movable curtain, called the *vail* of the palate, which hangs from the sides of the palate, so as to touch the tongue by its lower border. This partition opens, and allows the food to pass into a sort of funnel, called the *pharynx*, formed by the expansion of the top of the *œsophagus* or gullet, which leads to the stomach. This pharynx communicates above with the nostrils, and in front with the *larynx* or organ of the voice, which forms the upper part of the trachea.

135. The trachea or windpipe, being situated in front of the œsophagus, the alimentary ball must pass over the glottis or aperture of the windpipe. In order to prevent any of the food entering the windpipe, the larynx, in the very act of swallowing, is drawn beneath the base of the tongue; and this action presses down a little valve, called the epiglottis, upon the aperture, so as, in general, effectually to close it against the entrance of any solid or fluid particles. But it sometimes happens that if the breath be drawn in at the same instant, a particle of the food, or a drop of liquid, finds its way into the glottis, "passing the wrong way," as it is termed. In this case, violent coughing is excited, in order to drive the particle upward, and prevent it from falling to the lower part of the windpipe. The relative position of the œsophagus, windpipe, pharynx, &c. are shown in fig. 29.

136. After the morsel has passed by the glottis, the pharynx rises up to receive it, contracts, and forces it into the œsophagus, every part of which, as it is dilated by the morsel, is also stimulated to contract; and thus, by a succession of contractions, the food is carried through the whole length of the œsophagus into the stomach. The undulatory movement produced by these contractions is readily observed in the œsophagus of a horse, while he is drinking.

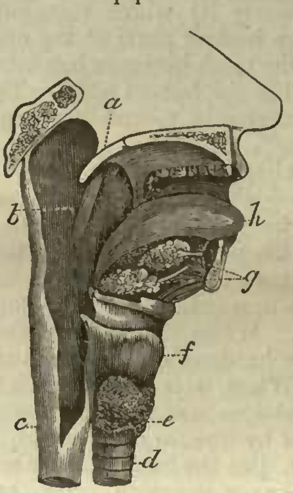

Fig. 29.—SECTION OF MOUTH AND THROAT.—*a*, vail of the palate; *b*, pharynx; *c*, œsophagus; *d*, trachea; *e*, thyroid gland; *f*, larynx; *g*, salivary glands; *h*, tongue.

CHYMIFICATION.

137. After passing through the œsophagus, the food arrives at the *stomach*, a membranous bag, placed across the upper part of the abdomen. The form of the stomach varies much, according to the nature of the food to be digested. In carnivorous animals, those of the cat-tribe, for example, whose food is flesh, which is easily dissolved, the stomach is small, and appears like a mere enlargement of the digestive tube. In herbivorous animals, on the contrary, whose food, being difficult of digestion, is delayed a long time in the stomach, that organ is very large, and frequently forms several bags or sacs.

138. By the degree in which the stomach bulges out, as it were, to the left side of the digestive tube, we can judge of the nature of the food, on which the animal lives. Thus, for example, in man, the large end of the stomach (fig. 31, and plate 4, fig. 1), situated on the left side, is moderately developed, showing that he is adapted to a mixed diet of animal and vegetable food. In purely carnivorous animals, the large end of the stomach is nearly wanting, while in those which feed solely on grass and grain, it is enormously developed.

§ 129. How are the teeth brought into action?—How do the movements of the lower jaw differ in different animals?—Describe the action of the jaw in carnivorous, herbivorous, and gnawing animals. 130. Why does the jaw of man combine these different modes of action?—What are the temporal muscles? 131. What is the act of insalivation?—What is said of its importance?—How is saliva secreted?—What are the names of the salivary glands, and where are they situated?—How is the quantity of saliva increased? 132. What is the purpose of the saliva? 133. What is said of the evil effects of imperfect mastication and insalivation?

§ 134. What is deglutition?—Explain the action of the vail of the palate in swallowing. 135. How is the food prevented from entering the windpipe?—What is the consequence when solid or fluid particles accidentally pass into the windpipe?—Refer to fig. 29, and describe the relative positions of the trachea, œsophagus, &c. 136. How is the food carried from the pharynx to the stomach?—Where may the contraction of the œsophagus be observed? 137. What is the stomach?—How does the form of the stomach vary?—What is said of the stomach of carnivorous animals?—of that of herbivorous animals? 138. How can we judge of the food on which an animal lives?—Give examples.

139. The most complex stomach is that of those animals which ruminate, or chew the cud. It possesses no less than four distinct cavities, as shown in fig. 30, which represents the stomach of a sheep. The food first enters the paunch or first stomach, and is there saturated with the fluid secreted by the walls of the stomach. It is next passed into the second cavity, which is called the reticular or honey-comb stomach, and which communicates directly with the œsophagus. The fluids, when swallowed, are passed at once into this stomach, without entering the first, and are absorbed into the system through the large surface presented by the folds of its lining membrane.

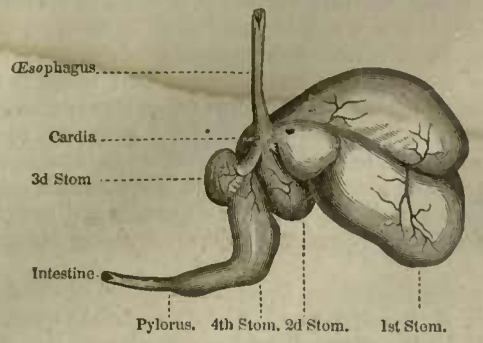

Fig. 30.—Stomach of the Sheep.

140. In the case of the camel, this reticular stomach contains that curious arrangement of water-cells by which the animal is enabled to retain a supply of water for several days. In the camel, the cells of the honey-comb stomach are much larger and deeper than in the sheep, and each of them may be closed at the top, by the drawing together of the sides of its orifice.

141. In this second stomach, the food transmitted from the first is rolled up into balls, which are returned at intervals through the œsophagus to the mouth, to undergo mastication and insalivation. During this "chewing of the cud," the animal seems the picture of quiet enjoyment. After being well masticated, the food is again swallowed, and then returns into the third, and fourth stomachs, successively, there to pass through the final process of digestion.

142. In birds, which do not masticate their food, some modification of the stomach is necessary, in order to reduce it. Accordingly, we find that in those birds which live on grain, the food is first moistened and softened in the *crop* or *craw*, just as it is in the paunch of the sheep. It then passes through the second stomach (in which the gastric juice is secreted) into the gizzard, which is a very strong hollow muscle, with a hard tendinous lining. In this the food is thoroughly triturated, the action of the gizzard being assisted, in many birds, as the common fowl, for instance, by pieces of gravel, swallowed for the purpose. In the rapacious birds, which live only on flesh or fish, the assistance of the gizzard is not required, since their food is easily digested, and is sufficiently divided into pieces, with the help of their beaks and claws. Their gizzard is consequently thin, and the cavities of the stomach are almost united into one. The digestive apparatus of the fowl is represented in plate 4, fig. 6.

143. In many insects, a powerful gizzard is also found, and is placed above the digestive stomach, instead of below it, as in the bird. In plate 4, fig. 7, is represented the digestive apparatus of a beetle. At *a*, is the head, with the jaws and antennæ. From this the gullet passes downward, and is dilated into a crop at *b*, below which is the gizzard, *c*, leading into the true digestive stomach, *d*, which is surrounded by great numbers of little bags or *follicles*, in which the gastric juice is secreted. Into this also open the long vessels, *e*, which in insects constitute the only rudiment of a liver.

144. In man, the stomach is an oblong, membranous bag, placed in the upper part of the abdomen, just below and partially behind the short ribs, and extending across from the left to the right side. Its capacity varies greatly. When distended, after a full meal, or after swallowing large quantities of drink, it may contain as much as two quarts. At other times, when quite empty, it may be contracted so as to hold not more than one pint. Perhaps its average capacity, in an adult person of moderate habits, may be reckoned at one quart.

145. The stomach has two openings; one, at the left end, called the *cardiac* orifice, because it is near the heart, leads upward into the œsophagus, and through it the food passes into the stomach. The other, at the right or small end, is called the *pyloric* orifice, and through it the partially digested food passes into the upper portion of the small intestine. The position of these openings, and the shape of the stomach may be seen by reference to fig. 31.

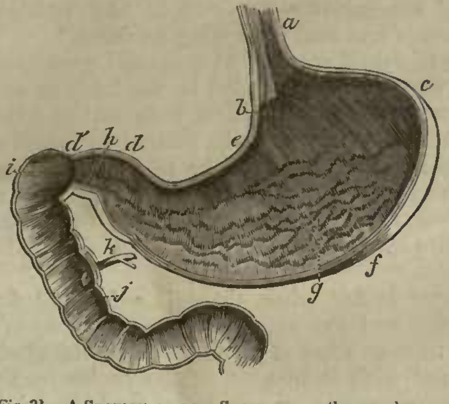

Fig. 31.—A Section of the Stomach.—*a*, the œsophagus; *b*, the cardiac orifice; *c*, the great end of the stomach; *d*, its lesser or pyloric end; *d′*, the pyloric orifice; *e*, the lesser curve; *f*, the greater curve; *g*, the rugæ or wrinkles of the mucous membrane; *h*, the pylorus; *i*, *j*, the duodenum, or first portion of the small intestine; *k*, the duct through which the bile and pancreatic juice are poured into the duodenum.

146. The stomach possesses three coats, each of which performs a separate office in the work of digestion. These are the outer or peritoneal, the middle or muscular, and the inner or mucous coats. The peritoneal coat is the same with the external coat of all the organs which are not exposed to the air. It lines the abdomen, and envelops in a sac all the organs found in the abdominal cavity, and sustains them in their respective places. This coat, like the pericardium (§ 65), pours out a constant secretion of fluid, which lubricates its surface, and prevents friction between the organs.

147. The muscular coat is composed of muscular fibres, such as we see in lean meat. These fibres possess great power of contraction and dilatation; drawing themselves up and being stretched out again, like india-rubber, without injury. Some of these fibres wind around the stomach in the form of rings; others run lengthwise from one end of the stomach to the other. Thus a double muscular coat is formed, of considerable thickness, and possessed of the power of contracting and dilating in every direction. By this alternate contracting and relaxing of its fibres, a great variety of motion is produced during the process of digestion, causing the food to be rolled about and moved successively over every portion of the inner or mucous coat.

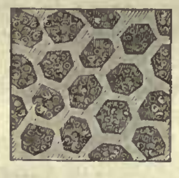

Fig. 32.—Mucous Membrane of the stomach magnified, showing the cells, with the mouths of tubes open at the bottom of each.

148. The mucous membrane (fig. 32) lines the inside of the stomach with a thick, soft, and loose investment. It is not elastic, like the other coats, but is drawn into folds when the stomach is contracted, and spreads out smoothly when it is dilated. This coat secretes a mucous or slimy matter, which protects the stomach from being unduly irritated by its contents, and it also pours out from numerous little follicles or glands the *gastric juice*, in which the food is dissolved.

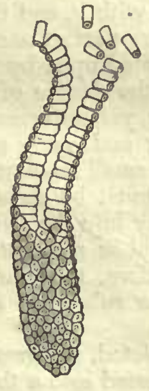

Fig. 33.—One of the tubular follicles of the stomach, magnified.

149. The gastric glands or follicles are of tubular form, ranging from 1-500 to 1-300 of an inch in diameter. Their form is shown in fig. 33. When there is no food in the stomach, these glands are at rest, and the gastric juice is not poured out. Immediately on the introduction of food, they commence secreting actively, and an acid fluid exudes in drops, which run down the walls of the stomach, and soak into the substances within it. The gastric juice is a very powerful solvent of all proper food of every kind, whether animal or vegetable. It is peculiar to the living stomach, and is indispensable to digestion.

150. The nature of the gastric fluid was first accurately ascertained by Dr. Beaumont, of the United States' army. He made many exceedingly interesting experiments, which have thrown great light on the whole process of digestion, and some of the results of which will be hereafter mentioned. A Canadian, named St. Martin, was wounded by a gun-shot, which produced an opening into his stomach near the cardiac orifice. The borders of the wound healed, and a valve or flap of membrane closed the opening from the inside, but could be pushed back with the finger. Through this means Dr. Beaumont

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§ 139. Describe the stomach of the sheep, and the passage of the food through its two first parts. 140. How is the camel enabled to retain a large supply of water in its stomach?—141. Describe the operation of "chewing the cud." 142. How is the absence of teeth compensated in the bird?—Describe the operation of the gizzard.—Refer to plate 4, fig. 6. 143. Describe the digestive apparatus of the beetle.—Refer to plate 4, fig. 7. 144. Describe the stomach of man.—What is its capacity? 145. What are the openings of the stomach called?—Explain fig. 31.

§ 146. What are the three coats of the stomach?—Describe the peritoneal coat. 147. Describe the muscular coat, and its action. 148. Describe the mucous coat, and its secretions. 149. What is said of the gastric glands or follicles?—When are they at rest, and when do they secrete the gastric fluid? 150. How was Dr. Beaumont enabled to make his experiments?—How does he describe the gastric juice?

was enabled to draw off portions of the gastric fluid, and to watch the entire operation of the stomach in digestion. He describes the gastric juice as "a clear, transparent fluid, inodorous, a little saltish, and very perceptibly acid. It is powerfully antiseptic, checking the putrefaction of meat; and effectually restorative of healthy action, when applied to old fetid sores and foul ulcerating surfaces."

151. The amount of gastric fluid secreted at one time corresponds with the quantity of food which is then needed by the body as nourishment. It begins to flow as soon as the first mouthful of food is received into the stomach, and continues to be poured out until the body requires no more aliment. If more food be taken than is sufficient for the wants of the system, it will remain undigested, and become a source of oppression and irritation; or, being mixed with that previously received into the stomach, the digestion of the whole is retarded.

152. The sense of hunger is felt when there is a demand for a fresh supply of nourishment, and the stomach is ready to form its secretion. If the food be then swallowed no faster than the gastric fluid is prepared to be mixed with it, hunger or the desire for food will cease when the secretion ceases, or when just food enough has been taken. But if the food be swallowed twice as fast as it can be supplied with gastric juice, the sense of hunger will continue till twice as much is taken as is actually required. Hence, those persons who live to eat, should eat as fast as possible; and those who eat to live, should eat no faster than the gastric juice is secreted, and they will then be sure to eat no more than nature requires. The consequences of rapid eating are insatiable appetite, nervous irritability, and dyspepsia or disease of the stomach. Rapid eating is a prevailing sin among the American people, and the practice cannot be too severely censured.

153. When the proper kind of food has been taken in proper quantities, the fibres of the muscular coat of the stomach alternately contract, pressing the mass of food forward and backward, and from side to side, exposing every part of it to the action of the gastric juice, until its solution is complete. This process lasts from two to five hours, or even longer, according to the kind of food, and the thoroughness with which it has been masticated. The agitation of the food is assisted by the action of the respiratory organs, in alternately raising and depressing the diaphragm, whenever the air is inhaled or expired from the lungs.

154. "The readiness with which the gastric fluid acts upon the several articles of food, is, in some measure, determined by the state of division, and of the tenderness and moisture of the substance presented to it. By minute division of the food, the extent of surface with which the digestive fluid can come in contact is increased, and its action proportionally accelerated." Hence the importance of thorough mastication. "Tender and moist substances offer less resistance to the action of the gastric juice than tough, hard, and dry ones do, because they may be thoroughly penetrated with it, and thus be attacked by it, not only at the surface, but at every part at once."

155. "The readiness with which a substance is acted upon by the gastric juice does not, however, necessarily imply the degree of its nutritive property; for a substance may be nutritious, yet, on account of its toughness or other qualities, hard to digest; and many soft, easily digested substances contain, comparatively, a small amount of nutriment. But for a substance to be nutritive, it must be capable of being assimilated to the blood; and to find its way into the blood, it must, if insoluble, be digestible by the gastric fluid or some other secretion in the intestinal canal. There is, therefore, thus far, a necessary connexion between the digestibility of a substance and its power of affording nutriment."

156. When the digestion in the stomach is completed, the gastric juice and the food are thoroughly mixed and converted into a thick pulpy mass, called *chyme.* Portions of chyme, as fast as they are formed, are sent through the pyloric orifice of the stomach into the *duodenum* or first portion of the alimentary canal (fig. 31, and plate 4, figs. 1, 2). Around the pyloric orifice, at the inside, is a thick band of muscular fibres, forming the kind of valve called *sphincter.* When digestion is not going on, this sphincter, as well as a similar one at the cardiac orifice, is firmly closed; and even in the first part of gastric digestion, the pyloric orifice is so completely closed, that none of the contents of the stomach can escape. But towards the termination of the digestive process, the pylorus offers less resistance. First, it yields, to allow the successively digested portions to go through it, and afterward, it allows the passage of even undigested portions. The latter are thus always retained in the stomach much longer than those portions which are properly digested, and produce the irritability and suffering so commonly felt after eating indigestible substances.

157. There are many circumstances, besides the nature of the food, which affect the process of chymification. Only a sufficient quantity should be taken to fairly fill the stomach, and not to distend it. Sufficient time should elapse, after each meal, to allow the stomach to become quite empty, before a fresh supply is taken. This interval may be generally stated at five or six hours, though it varies with the kind of food, and the condition of the stomach and system, generally. Gentle exercise, both previous and subsequent to the meal, is favorable to digestion, while excessive exertion, whether bodily or mental, retards it. A quiet and tranquil state of mind is also essential to quick and proper digestion. No man should eat his dinner in a passion. Drinks, taken in large quantities, materially interfere with the process of digestion. The juices secreted by the stomach itself are sufficient for the solution of most articles of diet; and whenever a superabundance of liquid is swallowed, the first effort of the stomach is to get rid of it. This it does, according to Dr. Beaumont's observations, by absorbing the liquid at once, and without change, through the blood-vessels in its mucous coat. The digestion of the thicker material cannot, then, be commenced until the liquid is disposed of.

158. A table was constructed by Dr. Beaumont, showing the periods required for the digestion of all the usual articles of food in St. Martin's stomach. Among the substances most quickly digested were rice and tripe, both of which were converted into chyme in an hour; eggs, trout, salmon, venison, and apples, were digested in an hour and a half; tapioca, barley, milk, liver, several kinds of fish, in two hours; turkey, lamb, potatoes, pig, in two hours and a half; beef and mutton required from three hours to three and a half, and veal a still longer time; fowls and mutton required the same length of time. Animal substances were generally chymified more rapidly than vegetables.

THE ALIMENTARY CANAL.

159. After undergoing the process of digestion in the stomach, the food is farther acted upon, and undergoes other changes, in the intestinal or alimentary canal. This canal is divided into two portions, named, from their difference in diameter, the *small* and the *large* intestines, which are separated from each other by a muscular valvular structure, the ilio-cœcal valve. This distinction is much less marked in carnivorous animals than in those which feed on vegetables, and the length of the whole canal differs greatly in the two orders. In the tiger, for instance, the intestines are about three times the length of the body; while in the sheep they are about twenty-eight times longer than the body, or seven times as long as those of the tiger, in proportion to the size of the animal. In those animals which live on a mixed diet, the intestines are of a medium length; thus in man, they measure about six times the length of the body.

160. The small intestine, for convenience of description, has been divided into three portions: the *duodenum,* into which opens the pyloric orifice of the stomach, and which is eight or ten inches long; the *jejunum,* which is continuous with the duodenum, and constitutes about two-fifths of the rest of the small intestine; and the *ilium,* which constitutes the remaining three-fifths. The large intestine is

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§ 151. To what does the amount of gastric juice secreted correspond?—If, then, more food than necessary be taken, what are the consequences? 152. When is hunger felt?—Why does hunger cease or continue, according as a proper or improper quantity of food is taken?—What is said of rapid eating, and its consequences? 153. Describe the muscular action of the stomach on the food.—How long does it continue?—How is the agitation of the food assisted? 154. How is the readiness with which the gastric juice acts, determined?—Why are tender and moist substances most readily acted upon? 155. Is the nutritive quality of a substance always proportioned to its easiness of digestion?—Explain this. 156. What is chyme?—Describe the passage of chyme into the duodenum.—Describe the pyloric sphincter, and its action.—Refer to plate 4, and point out the duodenum, pylorus, &c.

§ 157. Mention some of the circumstances which affect the process of chymification.—What are the effects of exercise, of tranquillity, of an excess of liquid? 158. Mention the different periods required for the digestion of various articles, according to Dr. Beaumont. 149. How is the intestinal canal divided?—What is said of the difference in the length of the intestines in the tiger and in the sheep?—What is the length of the human intestines? 160. What are the three divisions of the small intestine?—What are those of the large intestine?—How are the intestines sustained in their places?—What is the omentum?—Turn to plate 4, and point out the large and small intestines, &c.

PLATE IV.

ORGANS OF DIGESTION.

FIGURE 1.——GENERAL VIEW OF THE DIGESTIVE ORGANS OF MAN.

This figure is intended to give a general idea of the forms and relative positions of the organs of digestion.

a, The œsophagus. *b*, The stomach. *c*, The duodenum. *d, d, d*, Convolutions of the small intestine. *e*, The cœcum. *f*, Appendix of the cœcum. *g*, Opening of the small into the large intestine. *h*, The ascending colon. *i, i*, Transverse arch of the colon. *j*, The descending colon. *k*, The liver. *l*, The gall-bladder. *m*, The pancreas, mostly covered by the stomach. *o*, The spleen.—In this figure, the liver is raised up and the transverse arch of the colon drawn down, in order to show parts which they cover when in their natural situation.

FIGURE 2.——THE PANCREAS.

This figure is given to show more clearly the situation and connexions of the pancreas.

a, The pancreas. *b*, The duodenum. *c*, The gall-bladder. *d*, Duct of the gall-bladder, which communicates with the hepatic duct, *e*, which leads from the liver. *f*, Duct of the pancreas, which opens into the common bile-duct, *g*, through which the combined secretions of the pancreas and the liver are poured into the duodenum.

FIGURE 3.——SPHINCTER OF THE PYLORUS.

The figure represents this sphincter (*see* § 156), in its closed state. The central orifice dilates by the contraction of the band of fibres around it, whenever it is necessary for food to pass through it.

FIGURE 4.——INNER COAT OF THE STOMACH;

Showing its Rugæ or Folds when in a contracted state.

FIGURE 5.——GENERAL ASPECT OF THE ABDOMINAL VISCERA.

In this figure, the anterior walls of the abdomen are removed, so as to show the organs in their natural positions. The small intestine is removed.

a, The liver, situated beneath the right arch of the diaphragm. *b*, The stomach. *c*, Epiploa, or floating folds of the peritoneum. *d*, Summit of the gall-bladder. *e, e*, Large intestine, showing all its curves.

FIGURE 6.——DIGESTIVE APPARATUS OF FOWL.

a, Œsophagus. *b*, Crop. *c*, Second stomach, in which the gastric juice is secreted. *d*, Gizzard. *e*, Liver. *f*, Gall-bladder. *g*, Bile-ducts. *h*, Pancreas. *i*, Duodenum. *k*, Large intestine with its two cœca, *l*.

FIGURE 7.——DIGESTIVE APPARATUS OF BEETLE.

a, The head, jaws, &c. *b*, The crop. *c*, The gizzard. *d*, The true digestive stomach, surrounded by its follicles. *e*, The long vessels, which constitute a rudimentary liver.

FIGURES 8, 9.——THE LIVER.

Figure 8, represents the inferior face of the liver. *a*, The right or greater lobe. *b*, The left or smaller lobe. *c*, Groove which lodges the umbilical vein. *d*, Hepatic vena portæ. *e*, Hepatic artery. *f*, Inferior vena cava. *g*, Gall-bladder.

Figure 9, represents a section of the liver, showing the ramifications of the vessels. The hepatic vena portæ is a division of the abdominal vena portæ, into which empty all the veins of the digestive organs. It sends branches into all parts of the liver. After these branches have reached the capillary state, they are succeeded by the roots of the hepatic veins, which unite into three large veins which empty into the inferior vena cava.

FIGURE 10.——THE CHYLE-VESSELS AND THORACIC DUCT.

a, A portion of the small intestine. *b, b*, Origins of lacteals. *c*, Mesentery. *d*, Mesenteric glands. *e*, Lymphatic vessels. *f*, Thoracic duct. *g*, Aorta. *h*, Thoracic duct, curving downward and forward, to empty its chyle at the junctions of the left jugular and sub-clavian veins.

PRINCIPLES OF PHYSIOLOGY. ORGANS OF DIGESTION.

Fig. 1.

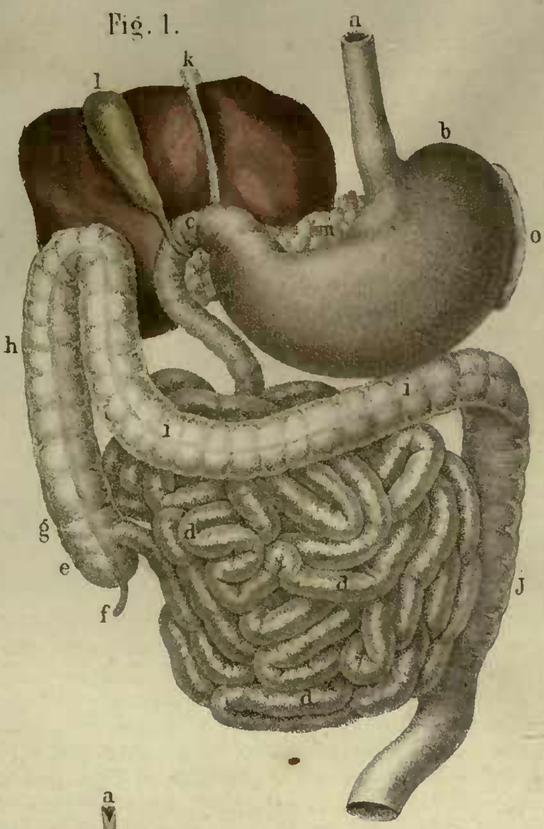


Fig. 2.

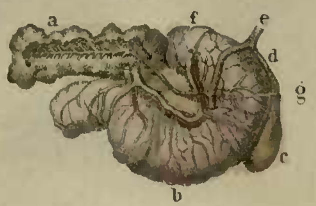


Fig. 3.

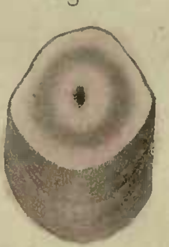


Fig. 4.

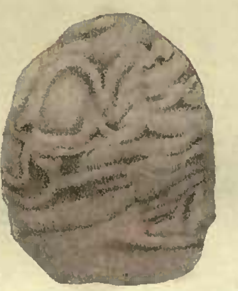


Fig. 5.

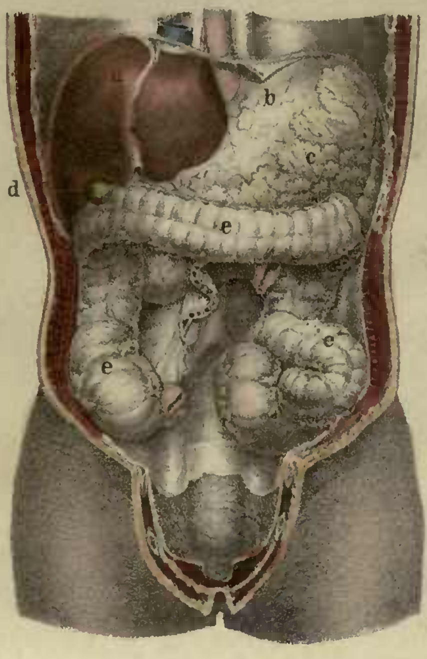


Fig. 6.

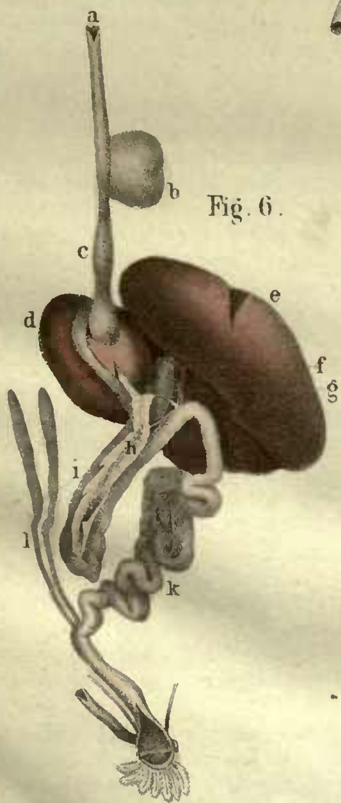


Fig. 7.

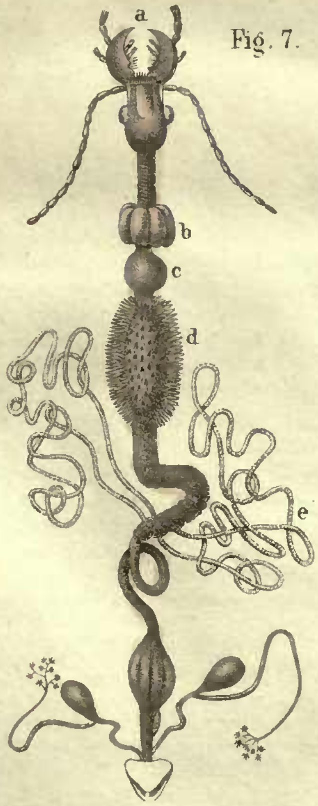


Fig. 8.

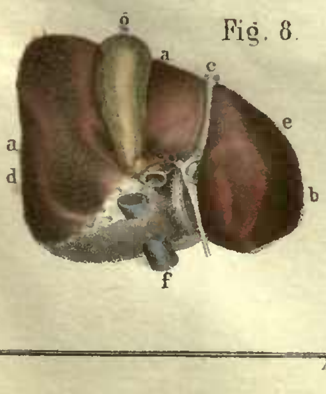


Fig. 9.

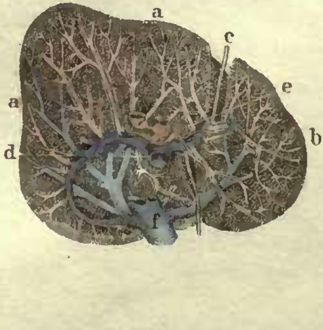
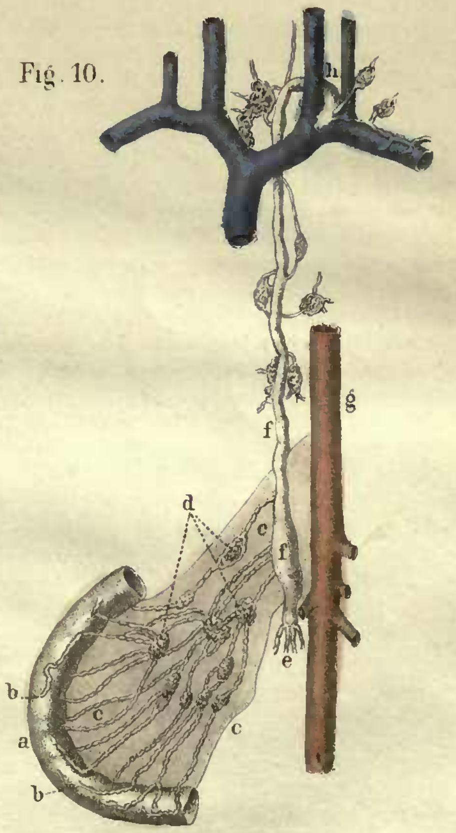


Fig. 10.



Lith of Kellogg

Entered according to Act of Congress in the year 1850, by Kellogg & Comstock, in the Clerk's Office of the District Court of Connecticut.

Hartford, Conn.

also divided into three portions: the *cæcum*, a short, wide pouch, separated from the small intestine by the ilio-cæcal valve; the *colon*, which forms the principal part of the large intestine, and is divided into an ascending, transverse, and descending portion; and the *rectum*, which terminates the whole canal. The intestines are sustained in their places, and suspended, as it were, from the spinal column by numerous folds of a serous membrane called the *peritoneum*. The *omentum* or caul consists of four of these folds, which pass around the stomach and colon. The *mesentery* is another portion of peritoneum, which connects the small intestines with the posterior wall of the abdomen. The relative positions of the intestines, as well as of the other organs of digestion, are shown in plate 4, which is to be referred to and studied in connexion with this chapter.

161. The intestines, like the stomach, are constructed of three coats, the peritoneal or serous, the muscular, and the mucous. The mucous membrane of the small intestine has its surface greatly extended by being formed in transverse folds, termed *valvulæ conniventes*. These folds commence in the duodenum (fig. 31). In the substance of the mucous membrane numerous glands are imbedded (one of which is represented in fig. 34), and the surface is studded with minute processes termed *villi*. The office of these villi is the absorption of nutritive matter from the completely digested food in the intestines. The mode in which this is performed, through a set of vessels called the *lacteals*, will be considered in the chapter on Absorption.

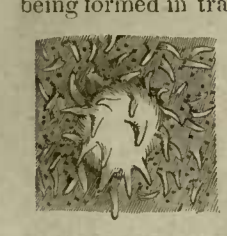


Fig. 34.—SINGLE GLAND OF SMALL INTESTINE.

162. It is chiefly in the small intestine that the process of digestion is continued and completed. After the chyme has passed into the duodenum, it becomes mixed with the bile secreted by the *liver*, and with the juice secreted by the *pancreas* or sweet-bread.

163. The pancreas is a long, narrow gland, situated within the curve of the duodenum, into which its duct opens, either through a small separate orifice, or through a duct common to itself and the liver. It bears a strong resemblance to the salivary glands, and the fluid which it secretes appears to be nearly identical with saliva. The exact purpose which the pancreatic juice serves, is not well understood. It is supposed to assist in digesting fatty matters, and rendering them fit for absorption.

164. The liver is the largest gland in the body. It is situated in the right side, below and in contact with the diaphragm, and is divided into several lobes. The liver communicates, through a duct, with a membranous sac at its lower side, called the *gall-cyst* or *gall-bladder*, into which the bile is poured, after being secreted. The gall-bladder thus serves as a reservoir to the bile. Its duct opens into the duct leading directly from the liver, and forms, with it, the common bile-duct, through which the bile is poured into the duodenum. The bile is a greenish yellow fluid, having an extremely bitter taste and a nauseous smell. It is constantly secreted by the liver; but during fasting, it accumulates in the gall-bladder, whence it is poured out, on the introduction of food into the stomach.

165. The effect of the mixture of bile and pancreatic juice with the chyme in the duodenum, is the production of *chyle*. The chyle is separated from the chyme, in the form of a whitish, milk-like fluid, with a sweet and somewhat saltish taste. It is, in fact, imperfectly elaborated blood, and nearly resembles blood in its constituent parts. The chyle is absorbed, as the digested food passes along through the small intestine, and the residue of the chyme, consisting of indigestible substances, gradually becomes more and more dry and hard, and is at length carried into the large intestine, and thence excreted from the system.

166. The food, and the several secretions mixed with it, are carried through the intestinal canal, and slowly exposed to the action of the absorbent vessels, by means of the *peristaltic* or *vermicular* movement of the intestines. This movement is effected by means of the successive contractions and dilatations of the intestinal coats, which extend in a wave-like manner throughout the tube. In health, this movement is slow, and generally unperceived by the mind; but it becomes very perceptible in diarrhœa, or when accelerated by the influence of purgatives. The movements of the intestines are sometimes backward or anti-peristaltic; and in such a case, the ilio-cæcal valve prevents the passage of the contents of the large into the small intestine.

CHAPTER VI.

ABSORPTION.

167. THE process of absorption has for one of its objects the introduction into the blood of fresh materials from the food and the air, and from whatever comes in contact with the external or internal surfaces of the body; and, for another object, the taking away of parts of the body itself, when, having fulfilled their office, or for some other reason, such parts need to be renewed. The first division of this function is therefore called absorption from without, or external absorption; and the second, absorption from within, or internal absorption.

168. In these operations, two sets of vessels are concerned; the blood-vessels, especially the veins, and the *lacteals* or lymphatics, to which the term absorbents has been especially applied. The *lymphatics* are distributed in nearly all parts of the body that contain blood-vessels, and they convey a fluid called *lymph;* the *lacteals* are exclusively confined to the intestinal canal, and convey the *chyle.* The difference between the lacteals and lymphatics is, however, more apparent than real. Their structure is nearly the same; they empty their contents into a common trunk; and the chyle of the lacteals is said to differ from the lymph only in containing, besides lymph, certain elements of food which give it its milky appearance.

169. Absorption by the lacteals has been called alimentary, digestive, or *nutritive absorption*, because, by its means, materials for nutrition are conveyed to the blood; while absorption by the lymphatics has been more generally named *interstitial absorption*, and regarded merely as the means by which the several parts of the body are cleared of their waste and excrementitious material. It is now considered most probable, however, that the latter purpose is effected by the absorption of the blood-vessels, and that the lymphatics, like the lacteals, absorb and elaborate principles capable of being employed for further purposes.

170. During the passage of the chyme along the intestinal canal, its completely digested parts are absorbed by the blood-vessels and lacteals distributed in the mucous membrane. The blood-vessels appear to absorb none but the dissolved or fluid portions of the food, and these they imbibe without choice, admitting every thing which can mix at once with the blood. But the lacteals absorb only certain constituents of the food, particularly including the fatty portions.

171. The lacteals commence in minute tubes from the villi of the small intestine below the point where the bile-duct enters, as already mentioned (§ 161). The lacteal trunk which issues from each villus is formed by several branches, anastomosing with each other. The villus has no orifice through which the chyle can pass into the lacteals; but each villus contains at its summit a number of small cells, in which it is supposed that the absorbent power is situated. A diagram of the mucous membrane of the intestine, with a villus and lacteal vessels, is represented in fig. 35, page 22.

172. The lymphatics, like the lacteals, consist of very slender, flattened, pellucid tubes, which present, at short distances, numerous constrictions, owing to the presence of small valves in their interior. These valves are similar to those of the veins (§ 86), and answer a like purpose. The lymphatics commence either in closely-meshed net-works interspersed among the proper elements and blood-vessels of the several tissues; or else in pointed closed tubes or processes from the vessels. No cells, similar to those of the villi, have been discovered to communicate with them. It has been supposed that

§ 161. What are the three coats of the intestines?—What are the valvulæ conniventes?—Refer to fig. 31.—What are the villi, and what is their office? 162. With what is the chyme mixed in the duodenum? 163. Describe the pancreas and its secretion.—Refer to plate 4, and point out its situation and duct. 164. What is said of the liver and its office?—What is the gall-bladder, and what is its office?—What is said of the bile?—Refer to plate, and describe the liver and gall-bladder. 165. What effect is produced by the mixture of bile and pancreatic juice with the chyme?—Describe chyle.—What farther changes take place as the food passes through the intestines? 166. What is the peristaltic movement of the intestines, and how is it effected?

§ 167. What are the objects of absorption?—What are the two divisions of absorption called? 168. What are the two sets of vessels concerned in absorption?—Describe the lymphatics and lacteals.—What is said of the difference between them, and of the similarity of their contents? 169. What has lacteal absorption been called, and why?—What has absorption by the lymphatics been named?—What is said of this distinction? 170. How are the digested parts of the chyme absorbed? 171. How do the blood-vessels and lacteals differ in their power of absorption? 172. Describe the lymphatics.

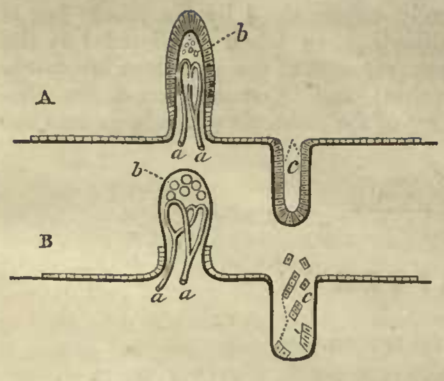


Fig. 35.—Diagram of Mucous Membrane.—A, in the intervals of digestion; B, during digestion; *a*, *a*, absorbent vessels; *b*, *b*, absorbent cells of a villus; *c*, *c*, pits or follicles between the villi.

they communicate, at their origin, directly with the blood-vessels, but there does not seem to be sufficient evidence of this, at least in the case of man.

173. "The real nature of the substances absorbed by the lymphatics, and the mode in which the absorption is effected," says Dr. Kirkes, "are still among the enigmas of physiology. It may, however, be held as highly probable, that the materials which it is the office of the lymphatics to absorb, are, like those commonly absorbed by the lacteals, chiefly of a nutritious kind, capable of higher organization and of contributing to the nutrition of the body." "On the whole," he adds, "it is most probable that the lymph is derived from the liquor sanguinis (§ 53); since changes in the character of the former usually correspond very closely with changes in the character of either the whole mass of blood, or of that in the part from which the lymph is examined."

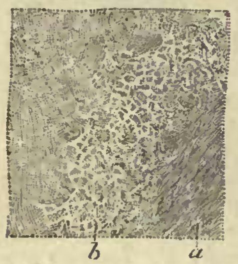


Fig. 36.—Appearance of Lymphatics in the Mucous Membrane of the Stomach.—*a*, superficial layer; *b*, deep layer.

174. During their course, both lacteals and lymphatics are frequently interrupted by wreaths or agglomerations, formed by the convolutions of their tubes, interwoven with minute blood-vessels, and resembling small glands. Those of the lacteals, as they pass between the folds of the mesentery, are called mesenteric glands. Those of the lymphatics are also called lymphatic ganglions, and are very abundant in the arm-pit, groin, and sides of the neck, where they sometimes become inflamed and swollen into painful lumps or tumors.

175. The lacteals and most of the lymphatics unite in forming a main trunk, called the *thoracic duct*, which constitutes their common reservoir. Its diameter is about that of a large quill. It is situated in front of the spinal column, and after passing upward to the height of the collar-bone, it suddenly turns forward and downward, and empties its contents into the stream of venous blood proceeding to the heart, through an orifice provided with a valve, at the angle formed by the junction of the internal jugular with the sub-clavian vein. By the union of these two veins is formed the left branch of the descending vena-cava. Plate 4, fig. 10, represents the course of the lacteals and lymphatics, and of the thoracic duct.

176. When the process of digestion is not going on, the fluid contained in the lacteals is clear and transparent, and exactly resembles lymph; but, during absorption from the chyme, it becomes milky, and acquires the other characters of chyle. The whiteness and opacity of chyle are owing to the presence of innumerable particles of oily or fatty matter. The fluid in which they float is albuminous. As the chyle passes upward through the mesenteric glands, and into the thoracic duct, cells, called chyle-corpuscles, become developed in it, and it acquires the power of coagulating spontaneously, forming a clot like that of the blood (§ 54), without the red corpuscles; thus showing that it contains fibrine.

177. *Lymph* is usually clear, transparent, and either colorless, or having a pale yellow tinge. It usually contains, when in the smaller vessels, no corpuscles or particles of any kind; but as it advances towards the thoracic duct, and passes through the lymphatic glands, corpuscles are developed, and it becomes like chyle, spontaneously coagulable, from the formation of fibrine. It thus appears that the essential characters of chyle and lymph are very nearly the same, and differ only in the greater quantity of fatty matter contained in the chyle.

178. Upon analyzing lymph and chyle, it is found that they contain essentially the same constituents as are found in the blood. Whatever difference there is between them and the blood, gradually diminishes as they pass through the thoracic duct and approach the place where they are to be mingled with the blood. In quality, therefore, they are adapted to replenish the blood, and their quantity appears ample for this purpose. From experiments upon animals, it has been estimated that in some cases, as in that of the cat, the quantity of lymph which daily passes through the thoracic duct is equal to the amount of blood at any time contained in the body.

179. The lymphatic and lacteal vessels not only contain, but move, the lymph and chyle. Their valves are turned towards the heart, like those of the veins, and are usually arranged in pairs; so that all muscular and other external pressure accelerates the flow of the lymph as it does that of the blood in the veins. In reptiles, and some birds, this movement is assisted by muscular sacs, called *lymph-hearts*. Into each of these cavities several lymphatics open, and from each leads a single vein which conveys the lymph directly into the blood. These hearts have a distinct pulsation, though more slow and feeble than that of the blood-heart.

180. In addition to their principal office, that of taking up a part of the worn out particles of matter, and again fitting them to the purposes of nutrition, the lymphatics also occasionally absorb substances which are placed in contact with the skin. This is sometimes called *accidental absorption;* and when the substance absorbed is of an acrid or poisonous nature, its passage may be traced by the red streak caused by inflammation of the lymphatic vessels. Unless arrested, the poison, in such cases, may spread rapidly, and even cause death. Liability to such results is greatly increased, when the poisonous matter comes in contact with a puncture or scratch in the skin, which exposes the absorbent vessels. The lives of many eminent medical men have been lost in this way, in consequence of a slight wound of the hand, while opening the bodies of persons who have died of particular diseases.

181. The function of absorbing from the skin, however, is principally effected by the blood-vessels, and especially by the veins. Unlike the lymphatics and lacteals, the blood-vessels seem to exercise no choice in the selection of the materials absorbed by them. They take up every substance, whether gaseous or liquid, or even minutely divided solids, without regard to quality, provided it can penetrate their walls and mix with the blood. The less dense the fluid to be absorbed, however, the more rapid is its absorption.

182. When the amount of fluid in the body has been greatly reduced, as after long fasting, absorption of fluid through the skin may take place in considerable quantity. A patient of Dr. Currie, who was was entirely unable to receive food into his stomach, was kept alive for several weeks by being immersed in a bath of milk and water. His weight did not diminish, and Dr. Currie estimates that from one to two pints of fluid must have passed daily through his skin. Numerous instances have occurred where shipwrecked sailors, suffering from thirst, have found themselves greatly relieved by dipping their clothes in the sea, and putting them on while wet. Even the moisture ordinarily contained in the atmosphere may be absorbed so rapidly as sensibly to increase the weight of the body, and it seems that this absorbing power is peculiarly excited by drinking a small quantity of wine or spirits, or some hot fluid. Thus it is related that a boy, who had been nearly starved, in order to reduce his weight for riding a match, increased nearly thirty ounces within an hour, though he had drank only half a glass of wine during that period. A similar fact is mentioned, where the increase was still greater, and was produced by drinking a cup of tea.

These instances will indicate the reasons why it is more dangerous when fasting, than after a full meal, to be exposed to the miasma contained in the air of the apartment of a person laboring under a contagious disease. Depression of mind, anxiety and fear, as well as every thing which tends to lessen the tone and vigor of the system, and to diminish the action of the heart and arteries, is also found to promote the activity of absorption. Hence, experience proves that during the prevalence of an epidemic which is propagated by an impure state of the atmosphere, those persons who most dread the

§ 173. What is said of the nature of the substances absorbed by the lymphatics?—From what is the lymph probably derived? 174. Describe the lymphatic and mesenteric glands? 175. What is the thoracic duct?—Describe its situation and course.—Refer to plate 4, fig 10. 176. What changes take place in the fluid of the lacteals?—To what is the whiteness of chyle owing?—What changes does it pass through in its course? 177. Describe lymph, and its changes. 178. How, then, are lymph and chyle adapted to replenish the blood?—What is said of the quantity of lymph, compared with that of the blood?

§ 179. How is the chyle moved in its vessels?—Describe the lymph-heart? 180. What is accidental absorption?—What is said of the absorption of poisons? 181. How is absorption from the skin principally effected?—How do the blood-vessels differ from the lymphatics and lacteals in the selection of materials for absorption? 182. When is absorption through the skin most active?—Relate the illustrations given of this.—How is the absorption of moisture peculiarly excited?—Give the illustrations.—What is said of other causes which promote absorption through the skin, and of their influence in infectious diseases?

disease are most liable to contract it; while, on the contrary, hope and confidence are among the surest preservatives. From this, also, we can understand how of two individuals who are exposed to contagion under exactly the same circumstances, one escapes all evil consequences, while the other dies.

CHAPTER VII.

NUTRITION AND GROWTH.

183. Nutrition is that vital process by which organs and tissues already formed are maintained in the same general conditions of shape, size, and composition, which they have obtained by development and growth. It is by this process that an adult person, in health, preserves, through a series of years, the same general outline of features, the same size and form, and, perhaps, even the same weight; although, during all this time, the several portions of his body are continually changing; their particles decaying and being removed, and then replaced by new ones, which, in their turn, also die and pass away.

184. Not only is the whole body thus preserved in its identity, but every organ and every part exactly maintains its form and composition. The loss consequent on the waste and natural decay of the particles is repaired by the introduction of fresh nutritive principles; and each elementary particle, in whatever tissue or organ it is found, seems to be capable of attracting materials from the blood, and causing them to assume its own peculiarities of structure. Thus, from apparently the same materials, the muscles form muscular substance, the nerves nervous substance, the bones bony substance, and so on.

185. The source of nutrition is the blood, from which each tissue draws those materials which it requires. The blood is distributed in the substance of the tissues by means of the capillary vessels (§ 85), and each tissue is supplied with a greater or less quantity of blood, in proportion to the degree of minuteness with which the capillaries ramify in it. Since the capillaries do not open directly into any tissue, no fluid can escape from them for the purpose of nourishment, except by passing through their walls. Hence it is supposed that none of the cells which float in the blood can be deposited in the tissues; but that the *liquor sanguinis* (§ 53) furnishes the elements of nutrition, since it readily permeates the walls of the capillaries, so as to arrive at the parts to which it is to be applied.

186. Some of the tissues, however, are not traversed by blood-vessels, but derive their nutriment by absorbing the *liquor sanguinis* which is brought into their neighborhood. This is the case, for instance, with the layer of cartilage which covers the ends of many of the bones, and which obtains the little nourishment it requires from the vessels which surround it. The changes which such tissues undergo are slow and limited, and there is, consequently, no necessity for an active circulation through them; while the delicate cellular or areolar tissue (§ 39), which is constantly passing through rapid and extensive changes, is, in general, most abundantly supplied with capillaries which traverse it in every direction.

187. As the *liquor sanguinis* is withdrawn from the blood, it is continually being rëformed from the food; but if it be not supplied in sufficient quantity by the latter, the nutrition of the body cannot take place with its proper energy. The same result happens, if its fibrine (§ 54) be not properly elaborated. The tissues are imperfectly nourished; and the strength of the body and the vigor of the mind become, consequently, alike impaired. "This imperfect elaboration," says Dr. Carpenter, "seems to be the essential condition of one of the most destructive diseases to which the human frame is liable—that commonly known as *consumption*. This is, however, but one out of several diseases which may result from the same state of constitution. If the fibrine of the blood be imperfectly elaborated, it is less fit to undergo organization; and, consequently, instead of being converted into living tissues, part of it is deposited as an unorganizable mass, in the state known to the medical man as *tubercle*." Such depositions in the lungs produce all the dreadful symptoms of consumption, and their result is almost always fatal. The means by which tubercular disease is most likely to be arrested in its first stages, therefore, is by invigorating the system by good food, active exercise, pure air, warm clothing, and cheerful occupations.

188. A remarkable example of the nutritive process is seen in the closing of a wound or the union of a broken bone. The neighboring vessels pour out their *liquor sanguinis*, or *coagulable lymph*, as it is called by the surgeon; this fills up the open space, and when it coagulates, it forms a connecting medium between the separate parts. The lymph soon begins to show a regular organization; fibres and cells appear in it; some of the cells break down into vessels, which form connexions with those in the nearest living part; the blood begins to circulate through the newly-forming tissue; and, in time, such change takes place in it as connects its several portions into fabrics resembling those with which they are connected—whether bone, nerve, or skin, until the union is complete.

189. Besides the impairment and change of composition to which all parts are subject in the discharge of their natural functions, they are all liable to decay and degeneration of their particles, even while their natural actions are not called forth. It may be proved that every particle of the body is formed for a certain period of existence in the ordinary conditions of active life; at the end of which period, if not previously destroyed by outward force or exercise, it degenerates and is absorbed, or dies and is cast out.

190. The hair and teeth are the simplest examples of this. An eye-lash, which naturally falls out, or can be drawn out without pain, is one that has lived its natural time, and has died and been separated from the living parts. Its death is spontaneous, independent of exercise or any mechanical external force—the natural termination of a certain period of life; and before it dies, provision has been made for its successor. In the case of the milk-tooth (§ 128), its crown dies as the new tooth comes, and is cast out like the dead hair; while its fang, with its nerves, vessels, and pulp, degenerates and is absorbed.

191. Similar to these processes is that which constitutes the ordinary nutrition of a part. Each elementary particle of the body, after attaining its perfect state of development and growth, remains in that state for a time; then dies or degenerates, and is cast out or absorbed, to make way for its successor. The length of life enjoyed by some, if not all, the parts, appears to be fixed and determinate. Thus the milk-teeth, just mentioned, fall out at a certain average age; and of the yearly moulting and change of plumage of birds, and shedding of the antlers and hair of beasts, the only explanation is, that these several organs have their appointed times of living, at the end of which they are cast off and replaced by others, which, in their turn, are to pass through the same changes.

192. Thus we see that from the first development of life in the infant, to the extinction of life in old age, the body is continually changing. The man is composed of different particles from those which constituted the child; the matter which forms the dead body is not the same which formed it while a living body a few years before. Many, even, of those particles which entered into the composition of our frames yesterday, do not belong to them to-day. The rapidity with which these changes are effected depends on a great variety of causes; on age, constitution, the state of health, and the texture of the individual parts. In the earlier periods of life, nutrition goes on rapidly, speedily producing the renewal of parts; but, as life advances, the changes occur more slowly. The soft parts, and those organs in which absorption and deposition are carried on with activity, are renewed more often than those of firmer texture and less active circulation.

193. In order that the process of nutrition may be perfectly accomplished, several conditions are necessary. Among these, one of the most important is a right state and composition of the blood, from

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§ 183. Define nutrition.—What are the effects of this process on the frame? 184. Explain the process still farther. 185. What is the source of nutrition?—How is the blood distributed to the tissues, and in what proportion?—Since the capillaries have no orifices, how must the nutritive fluid escape from them?—What part of the blood, then, is supposed to furnish the elements of nutrition? 186. What is said of those tissues which are not traversed by blood-vessels?—What of the difference between the changes undergone by such tissues and those which take place in the areolar tissue? 187. How is the *liquor sanguinis* rëformed?—If it is not sufficiently furnished, or if the fibrine is not properly elaborated, what are the consequences?—What is said of the causes of consumption?

§ 188. What is a remarkable example of the nutritive process?—Describe it. 189. What is said of natural decay? 190. What examples are given?—Describe the death of a hair, and of a tooth. 191. Describe the process of nutrition.—What is said of the fixed period of life enjoyed by some organs? 192. What is said of the constant changes of particles in the body?—What are the circumstances on which the rapidity of these changes depends?—193. What are some of the conditions of healthy nutrition?—How is the effect of the mind through the nervous system on nutrition illustrated?

which the materials of nutrition are derived. If the blood be impure, the effects of the improper material contained in it will be manifested by a general derangement of the tissues to which it is sent. A certain influence of the nervous system is another of these conditions. Sufficient proof of influence on nutrition, through the nervous system, is shown by the effect of the imagination in the production or cure of organic diseases. One, among numerous illustrations of this, is the case mentioned by Dr. Warren, of Boston, in which a large tumor on the neck of a female was absorbed, and entirely disappeared, after the application of a dead person's hand; which remedy the patient had adopted, through her conviction of its efficacy.

194. Another condition necessary to healthy nutrition, is a healthy state of the part to be nourished. This seems proved, by the very nature of the process. Since nutrition consists in the formation of new parts like those already existing, unless the latter be healthy, the former cannot be so. So long as a part is healthy, and the other conditions of healthy nutrition exist, it preserves its healthy state. But, according to the same law, if the structure of a part be diseased or altered, the diseased state is likely to be perpetuated. In certain chronic diseases, therefore, the impure state of the blood is maintained, notwithstanding all diversities of diet. The period in which an alteration of structure may be maintained by nutrition is not, however, unlimited; for there is a general tendency to return to the perfect state. Thus, after the body has undergone the alteration produced by vaccination, or by small-pox, it may return, after a time, to its original state; and the person may require re-vaccination, or may have the small-pox a second time.

GROWTH.

195. Growth consists in the increase of a part in bulk and weight, by the addition of particles similar to its own, but more than sufficient to replace those which it loses by waste or natural decay. The mode and conditions of growth are similar to those of nutrition, from which it differs only in degree. When parts have reached their ordinary size, they generally retain, through the adult period of life, nearly the same dimensions. But when a full-grown part is called upon to exercise its usual function in an unusual degree, the demand is met by a corresponding increase or growth of the part. Thus the skin increases in thickness in parts subjected to an unusual amount of pressure or friction, as in the sole of the foot, generally, or in the palms of the hands of those accustomed to rough manual labor. This is also the cause of the enlargement and increased hardness of the muscles, when actively exercised. Such a growth is a healthy process; but a part may grow by the deposit of unhealthy material in it, through an excess of nutrition; thus diminishing, instead of increasing, its fitness for its natural office. This is often seen in the undue deposition of fat, by means of which the body is rendered corpulent and unwieldy. Another example is that of the enlarged liver, so frequently the result of an intemperate use of alcoholic liquors. This kind of growth is called *hypertrophy;* that is, excess of nutrition.

CHAPTER VIII.

SECRETION.

196. Secretion is the process by which materials are separated from the blood and from the organs in which they are formed, for the purpose either of serving some office in the animal economy, or of being discharged from the body as useless substances. In the first case, both the materials separated, and the processes by which they are separated, are termed *secretions;* in the latter case, they are named *excretions.* Thus, by the process of secretion, bile is formed in the liver; and the bile thus formed is the secretion of the liver. Most of the secretions consist of substances which do not previously exist in the blood, but require special organs for their formation. The excretions, on the contrary, usually consist of substances which exist, ready-formed, in the blood, and are merely abstracted from it.

197. How so many different gaseous, fluid, and solid substances are formed out of the same material, the blood, no laws hitherto ascertained have enabled us to explain. The same power of formation exists in plants as well as in animals. By the sap of different plants, and in which, from whatever plant derived, no chemical analysis has detected the slightest difference, we see the most opposite and varying products elaborated. Thus the sap of the poppy produces the narcotic opium; that of the cherry-laurel, the deadly prussic acid; that of the olive, its oil. Acids are obtained from some, alkalies from others; sweet juices, nutritive principles, oils, and resins, from others. Even different parts of the same plant furnish different secretions. The oil of the olive, for instance, is found in the fleshy part of its fruit; and yet no trace of this oil can be detected in the sap of the vessels of any other part of the tree. So in animals, the nutritious milk is secreted in one organ, the bitter bile in another; and, as yet, the most careful examination of the blood has thrown no light on the reasons why, by the same process and out of the same fluid, these different secretions are formed. These are secrets which man cannot penetrate, mysteries which, for the present, at least, are hidden from his gaze; it is only the construction of the machinery by which the secretions are effected, and the properties which they possess, that he can investigate.

198. All the varieties of secreting apparatus, both in the animal and in the plant, contain *cells* (§ 29), by which the process of secretion is performed. These cells are arranged in different methods, according to the structure of the organ in which they are found. They have the power of separating the peculiar secretion from the blood of the membrane with which they are connected, and are continually bursting, and pouring forth their contents. At parts where it is necessary that the secretion should be particularly abundant, the secreting surface is increased by great numbers of little bags or bottles, called *follicles* (fig. 35, c), lined with cells.

199. The two principal divisions of the secreting apparatus are *membranes* and *glands.* The principal secreting membranes are the serous and mucous membranes, and the skin. The serous membranes form closed sacs, and exist wherever the free surfaces of viscera come in contact with each other. Their chief purpose is to furnish a smooth, moist surface, to facilitate the movements of the inclosed organ, and to prevent the injurious effects of friction; as in the case of the pericardium (§ 65), and the outer coat of the stomach (§ 146). A peculiar variety of serous membrane is also found at the ends of the bones, which secretes a thick fluid, called *synovia,* by which the joints are lubricated. The mucous membranes line all those passages by which internal parts communicate with the exterior. They are soft and velvety, and abundantly supplied with vessels. They line the whole digestive apparatus, from the mouth through the intestines; and the whole respiratory apparatus, from the nose to the minute divisions of the bronchi. They are covered with a delicate cuticle, called *epithelium,* which contains the secreting cells, and which renders the surface smooth.

200. The *secreting glands* are the organs to which the office of secretion is especially ascribed, since they appear to be occupied by this office alone. They are divided into different classes, according to the manner in which the cells are arranged. Sometimes they are in the form of simple tubes, as the gastric glands of the stomach (§ 149), or the sweat-glands of the skin, which will be hereafter described. Sometimes the gland is composed of an aggregation of small lobules, the cells of which open by minute ducts which converge and unite into larger and larger ducts, and at last into a common trunk, through which their united contents are carried to the point where their presence is needed. The structure of such a gland may be compared, in arrangement, to a bunch of grapes, as is represented in fig. 37. Examples of the latter kind are

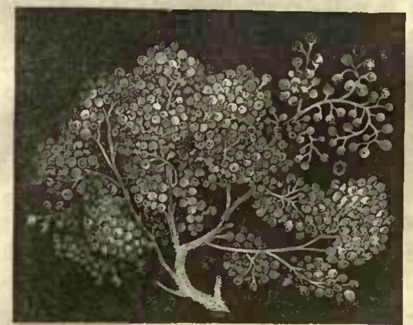

Fig. 37.—Structure of the Parotid Gland.

§ 194. What is another condition of healthy nutrition?—Explain the proof of this.—How is the tendency of the body to return to a perfect state shown? 195. What is growth?—What are the effects of exercise of a part?—What is said of hypertrophy? 196. What is secretion?—What are secretions?—What are excretions?

§ 197. What is said of the formation of so many different secretions out of the same materials? 198. By what is the process of secretion performed?—What is the character and operation of secreting cells?—What are follicles? 199. What are the principal divisions of the secreting organs?—What the principal secreting membranes?—Describe the serous membranes—the mucous membranes. 200. What are secreting glands, and their varieties?—Give examples of tubular and agglomerated glands.

the tonsils, the lachrymal gland which secretes the tears, the salivary glands, the pancreas, and the liver. In all these glands the blood is distributed by capillary vessels.

201. Those glands which secrete substances, the excretion of which is necessary for the purification of the blood, as the kidneys, which secrete the urine, generally discharge their secretions as soon as they are formed. Others, the secretions of which are only needed under particular circumstances, retain them until those circumstances occur. Thus, the lachrymal glands retain the tears, the salivary glands the saliva, until these secretions are called forth by their appropriate stimuli. The liver, as we have already seen (§ 164), has a reservoir, the gall-bladder, in which the bile is stored until needed for use. In the cow, the udders, in like manner, perform the office of a receptacle for the milk.

202. The quantity and character of the secretions are influenced by variations in the quantity of blood, and of the peculiar materials for any secretion which it contains, and by the condition of the nervous system. An increase in the quantity of blood which passes through a gland generally increases its secretions. Through the nerves, various emotions of the mind influence the secretions. Thus the thought of savory food increases the flow of saliva, and grief produces a flow of tears. In the case of milk, not only the quantity but the *quality* of the secretion is influenced. The more tranquil the temper and mind of the mother, the better adapted will her milk be for the nourishment of her offspring; and, on the other hand, there are several well-attested cases, where some violent passion of the mother has so changed the quality of her milk as to have instantly rendered it an absolute poison, which has caused the sudden death of her child.

203. The office of *excretion* is especially performed by the lungs, the liver, the kidneys, and the skin. The lungs, as we have seen (§ 102), throw off carbon and hydrogen, in the form of carbonic acid and vapor. The liver separates the same elements from the blood in the form of a peculiar fatty matter; the kidneys, in the form of urine; and the skin, in that of sweat. If these excretions, or either of them, be checked, they speedily accumulate in the blood, and sometimes lead to the most deleterious results. The biliary and urinary matters, when retained in the blood, produce the effect of narcotic poisons upon the brain, and as their amount is increased, these effects increase in intensity until death ensues. Whenever the liver does not properly perform its function, head-ache, languor, and nausea, are certain to come on. The great importance of the functions of secretion, and the necessity of carefully attending to them, cannot be too strongly enforced. In the next chapter, excretion by the skin will be specially considered.

CHAPTER IX.

THE SKIN.

204. The skin is one of the most important organs of the body, and a proper discharge of its various functions is indispensable to health, and even to life. As an external envelop, it protects and preserves the deeper tissues; as a sensitive organ, it is the seat of the sense of touch, through which we become acquainted with the characters of external objects; as an organ of excretion and absorption, it is next in importance to the liver and the kidneys. The office of the skin as a sensitive organ will be considered in that part of this work which treats of the sense of touch; this chapter will be confined to its general structure, and its functions of excretion and absorption.

205. The skin consists of two principal layers, the *cutis vera, corium*, or true skin; and the *epidermis, cuticle*, or scarf skin. The corium is a firm, elastic membrane, composed of innumerable fibres, interwoven in every direction, and traversed by a vast number of blood-vessels, lymphatics, and nerves. The fibres intercept spaces or areolæ, which, at its inner surface, are large and generally filled with fat; but at its outer surface, are nearly or quite obliterated. Within and beneath the corium lie perspiratory glands, hair follicles, and sebaceous or oil glands, and its outer surface is studded with minute conical elevations, called *papillæ*.

206. The papillæ are arranged in different modes, and are more densely set and more prominent in some parts of the body than in others. Thus they are readily seen in the palm of the hand, where each raised line is composed of a double row of them; and on the ends of the fingers, where they are disposed in concentric curves. In each papilla there is a net-work of minute blood-vessels, surrounding the extremity of a filament of a sensitive nerve. (5233).

207. The *epidermis* or outer skin, is a semi-transparent membrane, the thickness of which, on different portions of the body, is in proportion to the friction or pressure to which it is exposed; and the more it is subjected to friction or pressure, within certain limits, the thicker and more horny does it become. Thus, on the palm of the hand and the sole of the foot, it is thicker than any where else. Its principal office is to protect the sensitive corium from injury. In itself, the epidermis is insensible, and parts of it may be removed without pain.

208. "The epidermis consists of a vast number of minute cells, which are formed in layers upon the external surface of the true skin. In man, and most other soft-skinned animals, the outer layers of this epidermis are continually being worn off, and new layers are as constantly being formed from within. Thus each layer is gradually pushed from within outward; and its cells undergo a considerable change in their form, being nearly globular when first produced, and being gradually flattened into scales, by the loss of their contained fluids, as they approach the outer surface."

209. "It is in the latter condition that they are pressed together into that continuous membrane, which is raised by the fluid poured out from the surface of the true skin, where a blister has been applied, or a hot body has touched it. Where this membrane has been removed, some more delicate layers are seen upon the surface of the true skin, which consist of cells having more of the globular form, and not holding firmly together. These soft layers were formerly regarded as a distinct tissue, to which the name of *rete mucosum* (mucous network) was given; but this is now known to consist simply of the last-formed portions of the epidermis. It was supposed to be the peculiar seat of the coloring matter of the skin; this does not form a distinct layer, however, but is contained in *pigment cells*, which lie among the ordinary cells of the epidermis, and are consequently diffused through its whole thickness." The coloring matter contained in the pigment cells of the cuticle produces those varied tints which distinguish the complexions of different individuals and races.

210. From the translucence of the cuticle, the color of the parts beneath is seen through it, though the tints are modified by its not being perfectly transparent. When the surface of the body is exposed to a high degree of irritation, as by contact with fire, the vessels which pour out the lymph from which the cuticle is derived, are stimulated to increased action, and their fluid is effused so rapidly that it has no time to coagulate or be organized into cells. In this case it causes a separation between the cuticle and the true skin, and a *blister* is raised. When moderate irritation is applied, as that caused by friction or pressure, the increased amount of fluid has time to become organized, and the cuticle is rendered more thick and tough. It thus affords protection to the sensitive corium, at just those parts where the latter most needs protection.

211. The perspiratory glands are imbedded in the fatty layer beneath the skin, through which their ducts pass, twisting in a spiral manner, and opening at the surface of the cuticle, by a little valve or flap of which their orifice is covered. These glands are abundantly distributed over all parts of the body, and are especially numerous in the palm of the hand, where they have been estimated to amount to 3,528 in each superficial square inch. Their total number in the whole body has been reckoned at 7,000,000.

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§ 201. Explain the difference between glands, as relates to the discharge of their secretion.—Mention examples. 202. How are the quantity and character of the excretions influenced?—Give the instances of saliva, tears, and milk. 203. What organs specially perform excretion, and how?—What is the result, if the materials to be excreted are retained in the blood? 204. What is said of the importance of the skin?—What are its different functions? 205. What are the two layers of the skin?—Describe the cutis vera.—What organs lie beneath the true skin?—What are the papillæ?

§ 206. Describe the arrangement and construction of the papillæ. 207. Describe the epidermis.—Where is it thickest, and why? 207. Describe the construction and mode of renewal of the epidermis. 208. What are the pigment cells?—What do they contain? 210. How is a blister raised?—What is the effect of friction on the cuticle? 211. Describe the perspiratory glands.—Where are they most abundant, and what is their number?

212. The tubes of each of these glands being about one-quarter of an inch long, "it follows," says Erasmus Wilson, "that in a square inch of skin on the palm of the hand, there exists a length of tube equal to 882 inches, or 73½ feet. Surely such an amount of drainage as seventy-three feet in every square inch of skin—assuming this to be the average for the whole body—is something wonderful; and the thought naturally intrudes itself, What if this drainage be obstructed?

213. "To obtain an estimate of the length of tube of the perspiratory system of the whole surface of the body, I think that 2800 might be taken as a fair average of the number of pores in the square inch, and consequently 700, the number of inches in length. Now the number of square inches of surface in a man of ordinary height and bulk is 2500; the number of pores, therefore, 7,000,000; and the number of inches of perspiratory tube is 1,750,000; that is 145,833 feet, or 48,611 yards, or nearly *twenty-eight* miles."

214. The perspiratory glands constantly exhale fluid, which is usually formed so gradually that it is carried off by evaporation, as fast as it reaches the surface. In this case, it is called *insensible* perspiration. But during exercise, or exposure to heat, this secretion being poured forth in greater abundance than the air can dissolve and carry off, accumulates on the surface in drops, and is then named *sensible* perspiration. If the air be dry and warm, so as to carry off the fluid readily, the amount of insensible perspiration may be very great; but, on a damp day, when the air is already too much loaded with moisture to receive the additional quantity, the exhaled fluid will remain on the skin, and the uncomfortable effect produced by this is often experienced by a person wearing a water-proof garment, which keeps in the perspiration almost as effectually as it keeps out the rain.

215. "The purpose of this watery exhalation, and of its increase under a high temperature," says Dr. Carpenter, "is evidently to keep the heat of the body, as near as possible, to a uniform standard. By the evaporation of fluids from the surface of the skin, a considerable quantity of heat is withdrawn from it. The greater the amount of heat applied to the body, the more fluid is poured out by the perspiratory glands; and as the air can carry it off more readily, in proportion to its own heat, the evaporation becomes more rapid, and its cooling effect more powerful.

216. "It is in this manner that the body is rendered capable of sustaining very high degrees of external heat, without suffering injury." Thus, the workmen of Sir F. Chantrey, the sculptor, were in the habit of going into a furnace in which his moulds were dried, when the thermometer stood at 350°, and the floor of the furnace was red-hot; and Chabert, the 'Fire-King,' accustomed himself to enter an oven, at the temperature of 400° or 600°. The capability of many persons, employed in glass-blowing and iron-founding, to resist a very high degree of heat, is well known.

217. The quantity of watery vapor exhaled from the skin has been carefully estimated. M. Seguin inclosed himself in an air-tight bag, with a mouth-piece glued to his lips, so as to ascertain the difference between the amount of exhalation from the lungs and that from the skin. He found, by a long series of experiments made in this way, that the average daily amount of cutaneous exhalation was about two and a half pounds.

218. The existence of this exhalation may be easily tested by placing the naked hand and arm within a glass cylinder, or a wide-mouthed glass jar, winding a cloth around the arm at the mouth of the jar, so that the arm may not touch the glass. The inner surface of the jar will soon become dim with vapor, and the exhalation will collect into drops, and run down as a fluid.

This exhalation is composed of carbonic acid and water, together with other matters, which, when the perspiration becomes sensible, are deposited on the skin, and mixed with the sebaceous secretion. The importance of the excretory function of the skin, in carrying off such substances as would be injurious, if allowed to remain in the blood, and the benefit of removing such portions of the perspiration as may collect on the surface, impeding the pores and preventing the free action of the perspiratory glands, will be enlarged upon hereafter.

219. The fact, that the absorption of fluids takes place through the skin, even when covered by its cuticle, though long disputed, may now be considered as well established. In the lower animals, experiment has shown that such absorption may go on very rapidly. Not only frogs, whose skin is thin, but lizards, whose cuticle is thicker than that of man, after having lost weight by being kept in a dry atmosphere, quickly recovered their weight and plumpness, when immersed in water; and when only the tail and lower parts of the body of the lizard were immersed, the absorbed water was distributed through the system.

220. In the case of man, it has been ascertained by Dr. Madden, in ten experiments upon himself, that there was an average absorption, by the surface of the body, of four drachms, one scruple, and three grains, in half an hour. We have seen (§ 182) that life may be sustained for a considerable period, by means of the introduction of nutritious substances into the system, through the agency of this function of the skin.

221. Besides the perspiration, the skin secretes a peculiar fatty substance, and for this purpose is provided with another set of glands, called *sebaceous glands*. They are most abundant in those parts most largely supplied with hair, as the scalp and face, and are thickly distributed in the nose, lips, and ears. They are entirely absent from the palms of the hands, and the soles of the feet. Their ducts open either on the surface of the skin, or directly into the follicles of the hair. The fatty secretion of these glands seems to keep the skin smooth and supple, preventing it from drying up and cracking, and also from the effects of moisture. The contents of these glands, in the nose and forehead, often remain in their ducts, and become hardened, so that, when pressed out, they assume the cylindrical shape of the duct, and are then called *worms*. It has, in fact, been discovered that the ducts of the sebaceous glands are inhabited by a minute insect, closely resembling the cheese-mite.

Along the margin of the eyelids there is a row of these glands, like a string of beads. They furnish a thick fluid, which keeps the eyelids sufficiently slippery and smooth, and prevents the tears from trickling over the margin. Occasionally, one of these glands becomes inflamed, and produces what is called a *stye*. In the passages of the ears, another set of these glands is arranged in clusters, and secretes the ear-wax. This secretion, being of a resinous nature, serves to facilitate the transmission of sound, while, at the same time, it repels moisture, and its disagreeable odor and taste make it a good means of preventing the entrance of insects.

222. The *hair* and *nails* are appendages of the skin. Each hair originates in a small follicle or bag, the lower part of which is seated in the sub-cutaneous fat. Sebaceous glands open into these follicles, and furnish the oily material with which the hair is anointed and softened. The coloring matter of the hair is secreted by cells within the follicle, and, through a deficiency of this secretion, the hair becomes gray, and finally white. Each hair is formed of a compact outer wall, with a porous and cellular centre.

The uses of the hair are various. In many parts of the body it serves for ornament; on the head, it protects the brain from injury, and maintains an even temperature of that important organ; in the nose and ears, it prevents the passage of insects or other foreign bodies; on the eyebrows and eyelashes, it shades and guards the eye.

The nails are inserted between folds of the skin, which is reflected backward to the root of the nail, and then passes forward beneath its concave surface, to which it adheres. Their structure, like that of the scales, feathers, hoofs, and horns, of different animals, is similar to that of the epidermis, to which they belong. The use of the nails is to strengthen and support the ends of the fingers and toes; they afford a support to the fingers in grasping, and are particularly useful in taking hold of minute objects. Plate 5 is to be referred to, and studied, in connexion with the physiology of the skin.

§ 212. What is Wilson's estimate of the aggregate length of the perspiratory tubes in a square inch of skin?—What are his remarks on the subject? 213. What is Wilson's estimate of the whole length of the perspiratory tubes in the body?—How does he arrive at this conclusion? 214. What is insensible perspiration?—What is sensible perspiration?—What is the reason of the discomfort produced by wearing a water-proof coat? 215. What is the purpose of the perspiration, and of its increase under a high temperature? 216. How is the cooling effect of the evaporation of perspiration shown.—Mention the examples. 217. What was M. Seguin's experiment, and what is the amount of cutaneous exhalation, according to his estimate? 218. How may the existence of this exhalation be tested?—Of what is this exhalation composed?—What is said of the importance of the excretory function of the skin?

§ 219. How is it shown that cutaneous absorption takes place? 220. What is Dr. Madden's estimate of the average amount of absorption by the surface of the body? 221. What are the sebaceous glands?—Where are they most abundant?—What is the use of their secretion?—What is said of the contents of these glands remaining in their ducts?—By what are these ducts inhabited?—How are these glands arranged in the eyelids?—What is the use of their secretion?—What is the cause of a *stye*?—What is the use of the ear-wax? 222. Describe the origin, structure, and uses of the hair?—What is said of the nails?

PLATE V.

THE SKIN.

FIGURE 1.——A PORTION OF THE EPIDERMIS OF THE PALM OF THE HAND,

MAGNIFIED BY A SIMPLE LENS,

Showing the direction of the rugæ or wrinkles, and the arrangement of the apertures of the sudoriferous glands.

FIGURE 2.——A PORTION OF THE SAME,

MAGNIFIED ONE HUNDRED DIAMETERS.

FIGURE 3.——A TRANSVERSE SECTION OF THE RIDGES OF THE EPIDERMIS OF THE PALM OF THE HAND,

Showing a side view of the apertures of the sudoriferous glands, their spiral ducts, the thickness of the epidermis in that situation, its composition of layers of cells, and its mode of connexion with the true skin.

FIGURE 4.——A PORTION OF THE EPIDERMIS FROM THE BACK OF THE HAND,

Showing the disposition of the folds in that situation, the arrangement of the papillæ, the disposition of the hairs, and the apertures of the sudoriferous and sebaceous glands, magnified with a simple lens.

FIGURE 5.——A PIECE OF THE SAME,

MAGNIFIED ONE HUNDRED DIAMETERS,

Showing that each line is a furrow or groove, a provision which allows of very great extension of the epidermis.

FIGURE 6.——A SQUARE OF CUTICLE,

SEEN UPON ITS INTERNAL SURFACE.

a, The sulci, or depressions, which correspond with the ridges of the external surface. *b*, The ridges which correspond with the furrows of the external surface.

FIGURE 7.——THE UNDER SURFACE OF THE EPIDERMIS,

Showing the pigment-cells, which contain the coloring matter of the skin.—These cells are seen to be collected principally in the furrows between the papillæ.

FIGURE 8.——THE PIGMENT-CELLS OF THE NEGRO,

Showing that his darker complexion is owing to the darkness of the color of the pigment contained in these cells.

FIGURE 9.——A SECTION OF THE SKIN,

Showing the hair follicles and sebaceous glands. *a, a*, Sebaceous glands, opening into the hair follicle. *b*, A hair, with its follicle, *c*, surrounded by fat-cells.

FIGURE 10.——A SECTION OF ALL THE LAYERS OF THE SKIN.

a, The epidermis. *b, c*, The two layers of the cutis vera. *d*, A sweat-gland, surrounded by cells of fat, and sending its spiral duct upward through all the layers of the skin to the surface.

FIGURE 11.——A SECTION OF THE THUMB,

Showing the manner in which the nail is inserted between the folds of the skin.—*a*, The last bone of the thumb. *b*, The cuticle reflected upon the root of the nail. *c*, The nail. *d*, The cuticle of the point of the thumb, continuous with that at the inner surface of the nail.

PRINCIPLES of PHYSIOLOGY. THE SKIN.

Fig. 1.

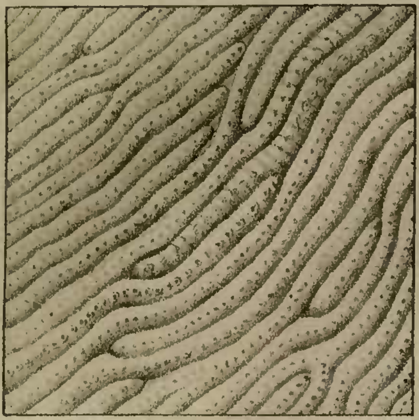
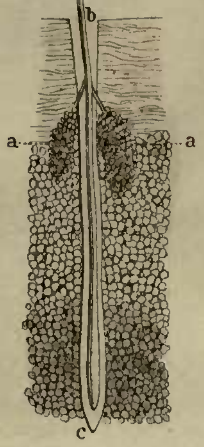


Fig. 9.



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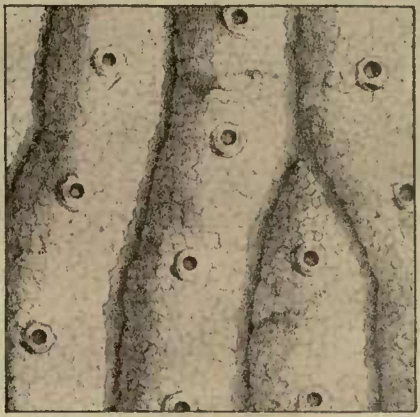

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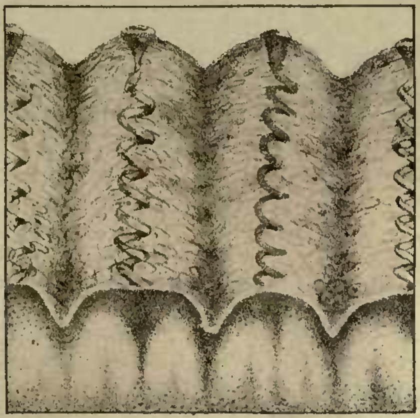

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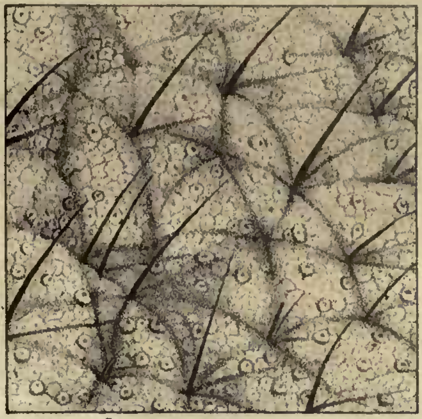

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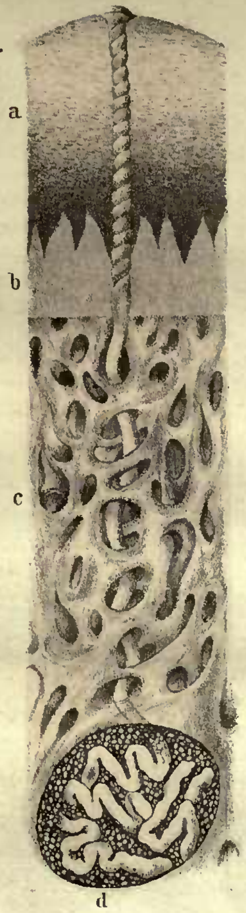

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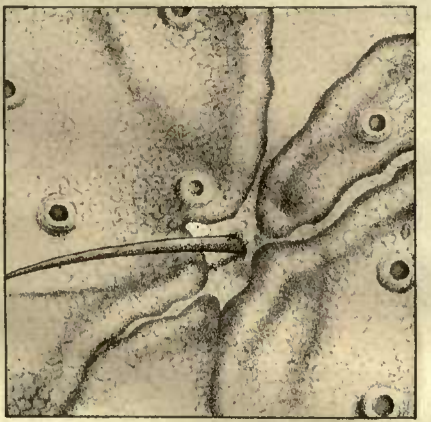

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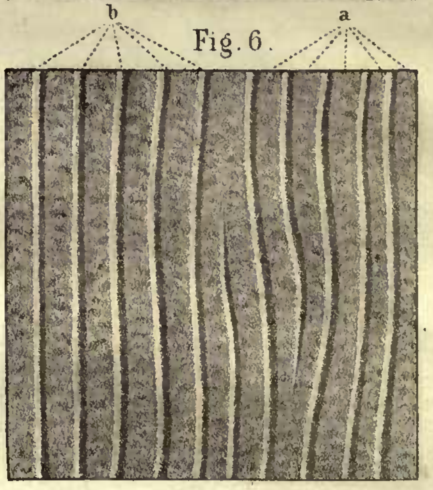

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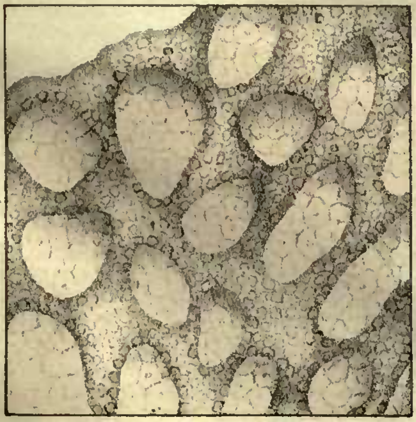

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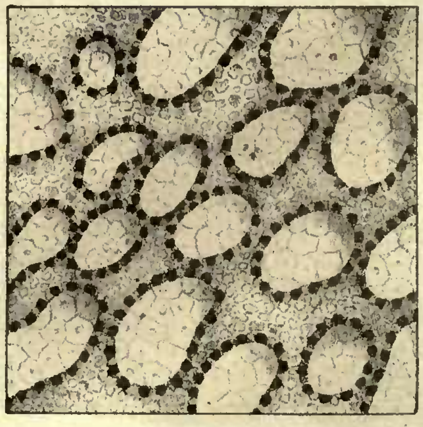

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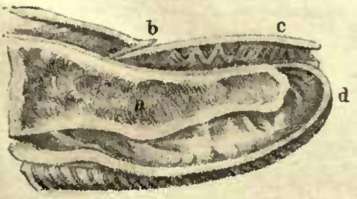

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CHAPTER X.

THE NERVOUS SYSTEM.

223. The functions of *organic life* have been considered in the former chapters, and we have seen that the immediate object of those functions is to form living organized tissue out of the materials taken into the body as food. We also find that the whole animal structure is formed for *motion*, and that every act of motion involves a decay or waste of the fabric by which it is executed. An energetic performance of the nutritive actions is required, therefore, in the more active animals, simply to make good the loss which in this way takes place. Thus we may say that the ultimate purpose of the organic life of animals is "to construct and to maintain, in a state fit for use, the mechanism which is to serve as the instrument of their *animal functions;* enabling them to receive sensation, and to execute spontaneous movements, in accordance with their emotions, instincts, or will."

224. "This mechanism consists of two kinds of structure, the *Nervous* and the *Muscular;* which have entirely different offices to perform. The *Nervous system* is that which is the actual instrument of the *mind*. Through its means, the individual becomes conscious of what is passing around him; its operations are connected, in a manner we are totally unable to explain, with all his thoughts, feelings, desires, reasonings, and determinations; and it communicates the influence of these to his muscles, exciting them to the operations which he desires or determines to execute. But, *of itself*, it cannot produce any movement, or give rise to any action; any more than the expansive force of steam could set a mill in motion, without the machinery of the steam engine for it to act upon. The *Muscular system* is the apparatus by which the movements of the body are immediately accomplished; and these it effects by the peculiar property it possesses of contracting, upon the application of certain *stimuli*, of which Nervous Agency is the most powerful."

225. In its combined action, the nervous system may be regarded as the instrument of sensation, of voluntary motion, and of mind. In the lowest orders of animals, it serves no higher purpose than to render the individual conscious of the presence of foreign bodies, and to give it power voluntarily to receive, by appropriate organs, whatever may contribute to nourishment, and to avoid or reject whatever may be injurious or useless. At each step in its progressive development, it becomes the medium of the manifestation of higher powers and faculties, until in the human species it attains its perfection, and becomes the instrument of those phenomena of mind and thought which dignify and ennoble man. Forming, as it does, the bond of union between the physical and intellectual conditions of the constitution of man, its study is equally interesting and important, whether in connexion with the science of Physiology, or with that of Mental Philosophy. Upon no branch of Physiology has so much been written, or have so many contradictory opinions been advanced, as that which comprises the functions of the nervous system; and the most subtle and powerful intellects have as yet failed to elucidate many of the mysteries connected with it. In this work, therefore, controverted points are as much as possible avoided, and an attempt will only be made to give a clear and concise account of it and its functions.

GENERAL STRUCTURE AND ACTIONS OF THE NERVOUS SYSTEM.

226. The nervous system consists of two kinds of structure; the *white* or *fibrous*, and the *gray* or *vesicular*. The *nerves* themselves, or the cords through which the nervous agency is communicated, are entirely composed of the white substance; while the vesicular or gray substance is usually mingled with the fibrous structure, and collected into masses, as in the brain, spinal cord, and *ganglia* or knots of nervous matter; and these masses constitute what are called *nervous centres,* because they are considered the organs in which the nervous force may be generated.

227. The *white* tissue consists of minute fibres, which under the microscope are found to be little tubes, transparent like glass, and containing a clear oil-like or pulpy substance, which may be squeezed from their ends when cut off. Each of these tubules proceeds without interruption from the nervous centre with which the nerve is connected, to the point at which it terminates, without uniting with any other. To form a nerve, these tubules are arranged in parallel or interlacing bundles or fasciculi, and these bundles are connected by fibro-cellular tissue, which also forms a sheath, called *neurilemma*, for the nerve.

228. The office of this kind of nervous structure is two-fold; first, to convey impressions made upon the extremities of the nerves to the brain, or other nervous centre, whereby the mind becomes conscious of external objects; and second, to convey impressions from the brain to the ultimate distributions of the nerves. The nerves are, therefore, divided into two classes; nerves of *sensation* and nerves of *motion*.

229. Thus, if the hand be accidentally placed in contact with a hot iron, the feeling of pain is communicated to the brain by the nerves of sensation, and the impulse to remove the hand is immediately returned from the brain by the nerves of motion. There is, however, no apparent difference in the structure of the nerve-fibres. Indeed, fibres of sensation and of motion may be included in the same bundle, in their distribution, though each set has a distinct and separate origin from the nervous centre. Nerves have no power of *originating* impressions. Those of sensation are stimulated by external agents, and those of motion by the will or some other force generated in the nervous centres.

230. Nervous force travels along a nerve like the electric fluid along a wire, without the lapse of an appreciable period of time in its passage. Each nerve-fibre can carry only one kind of impression. A nerve of motion can convey only motor impulses; a sensitive fibre can transmit only such as may produce sensation, if propagated to the brain. Moreover, the fibres of a nerve of special sense, as those of the eye or ear (optic or auditory nerves) can convey only such impressions as may produce a peculiar sensation, as that of light or sound.

231. The *gray* or *vesicular* nervous substance is very different from the other, both in its structure and functions. It is composed of great numbers of vesicles or nerve-corpuscles, lying in the interstices of a net-work of minute blood-vessels. It is found in the interior of the ganglia or nervous centres of all animals, and in the brain and spinal cord of those which possess a vertebral column or back-bone. In the brain, it is often called the *cortical* (bark-like) substance, because it forms a thin outer layer, inclosing the white substance, of which the greater part of the brain is composed.

232. "The precise manner in which this structure acts, we are unable to define; but this much is tolerably certain: that, in the gray matter of the nervous centres, all those changes originate which are propagated by the motor-fibres to the muscles; and that these changes depend upon the continual supply of arterial blood. If this supply be cut off by failure of the heart's action (as in ordinary fainting), or by pressure on the vessels which carry blood to the head, immediate insensibility, with loss of all power of motion, is the result."

233. The fibres of motor nerves, which are distributed to the muscles, spread forth from their trunks into branches which anastomose with each other, forming a kind of net-work through the muscle. But the nerves of sensation, which start from the skin, and convey impressions to the brain, originate in minute elevations or papillæ on the surface of the corium or true skin, and in their infinite ramifications is seated the sense of touch. In every one of these papillæ (see plate 5) is a net-work of minute vessels, interspersed with cells, which thus forms a sort of gray substance around the extremity of the nerve-fibre, and the influence of which is carried by the sensitive nerves to the brain, just as the influence of the brain is carried through the motor nerves to the muscles.

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§ 223. What is the immediate object of the functions of organic life?—What is the consequence of every act of motion?—Why is the energetic performance of the nutritive actions required?—What, then, may we say, is the ultimate purpose of organic life? 224. Of what does this mechanism consist?—What is the nervous system, and what is said of its operations?—Can this system, *of itself*, produce any movement?—How are the movements of the body accomplished? 225. What is said of the combined action of the nervous system?—What of its function in the lower animals?—What of its progressive development, the importance of its study, &c.? 226. Of what two kinds of structure does the nervous tissue consist?—Of which of these are the *nerves* themselves composed?—Where is the gray substance found?—What are nervous centres, and why are they so called?

§ 227. Describe the white tissue, and the manner in which it forms the nerves. 228. What is the office of the white tissue?—How are nerves divided? 229. Give the example of the distinct actions of the two classes of nerves.—What is said of the difference in the structure of the nerve-fibres?—How are the nerves of sensation stimulated?—How are those of motion stimulated?—Can nerves *originate* impressions? 230. What is said of nervous force, and of the peculiar impressions conveyed by each class of nerves? 231. What is said of the gray nerve-substance?—Where is it found?—What is it called in the brain? 232. What changes originate in it, and upon what do they depend?—What is the consequence, if the supply of blood be stopped? 233. What is said of the distribution of motor-fibres?—What of the origin of the sensitive fibres?—Describe the structure of the papillæ.—

234. "Hence we find that, before the mind of an individual can become conscious of what is passing around him, a change or *impression* must be effected by external objects upon the origins of the sensory nerves in the papillæ; this impression must be *conducted* by the nervous trunk to the sensorium (brain or other centre of perception), and there it becomes a *sensation*. On the other hand, before the mind can direct the body to perform any movement, an *emotion*, or an act of the *will*, must produce a change at the origin of the motor nerves in the brain, and this change is conducted along the motor trunks to the muscles, where it excites a *contraction* adapted to the required purpose."

235. It is by actions of this kind that the nervous system ministers to the *animal functions* (§ 15). But there is another set of movements, controlled by it, which are concerned in the maintenance of *organic life;* such, for instance, as those of Deglutition and Respiration. "These movements require the same double set of nervous fibres, and the same kind of nervous centre, containing gray matter; but they do *not* require that *sensation* should intervene, or (in other words), that the individual should become *conscious* of the impression in which they originate, in order that the muscles may be excited to contraction. Movements of this class are termed *reflex;* from the peculiar action of the nervous centre in throwing back, or reflecting, along the motor nerves which pass from it, the impression which it receives from the fibres that pass towards it."

236. "There can never be more than a single centre of *sensation* in any animal; for if there were two, or more, there must be two sets of feelings, and consequently two distinct individual minds. But there may be many centres of reflex action, having different purposes, because connected with different functions. In the lower classes of animals, these centres are often very numerous; and the actions to which they minister constitute a great part of the movements performed by them. But as we ascend the scale, we find that these centres of reflex action are less important, in comparison with the organ by which the mind operates; and the body is more influenced by the latter than by the former."

COMPARATIVE VIEW OF THE NERVOUS SYSTEM IN DIFFERENT GROUPS OF ANIMALS.

237. To illustrate the comparative importance of the different portions of the nervous system, it will be proper to begin with its simplest forms, and proceed gradually to the more complicated. As we thus examine the peculiarities of this system in the different groups of animals, we shall the better understand the mutual relations of its parts to each other, and shall be enabled to trace the gradual development of the powers connected with it. Nature has, in this way, furnished us with living demonstrations of the uses and functions of the complex parts which make up our own nervous system.

238. One of the simplest forms of the nervous system is shown by fig. 39. The animal to which it belongs is the *Ascidia*, one of the lowest of the class Mollusca, of which the slug and snail are higher members. In this and similar animals, we find only a single ganglion, or nervous centre. At *a* is seen the orifice by which water enters for supplying the stomach with food; and at *b*, that through which it passes out again. Between these orifices is the single ganglion, *c*, which sends filaments to both orifices, and also over the surface of the envelop or *mantle, d*. These animals are mostly fixed to one spot during their whole existence. The continual entrance and exit of the currents of water constitute the only phenomena of life which they exhibit, except when the current draws in any injurious substance. The mantle then contracts, causing a jet of water to issue from each orifice, and throwing off the offending material. This little animal has no eyes or other organ of special sense. The small *tentacula* or feelers, at the upper orifice, are the only parts which seem to be peculiarly sensitive; and the irritation caused by the contact of a hard substance with these, or with the general surface of the body, causes an *instinctive* contraction of the mantle, for the purpose of getting rid of the irritating cause. This contraction can only be performed by the aid of a nervous system, which has the power of receiving impressions, and of exciting the most distant parts of the body to act in accordance with them.

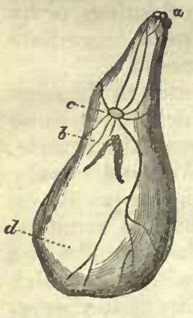

Fig. 39.—Nervous System of Ascidia.

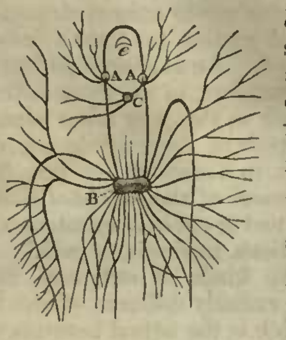

Fig. 40—Nervous System of Pecten.—A, A, ganglia of the head; B, respiratory ganglion; C, ganglion of the foot; *e*, œsophagus.

239. In those animals which inhabit *bivalve* shells, the powers of respiration, sensation, and voluntary motion, are evinced, and the nervous system is correspondingly developed. The nervous system of the *Pecten*, or Scallop-shell, is shown in fig. 40. At B is a large ganglion, which distributes branches to the gills and mantle, and regulates the respiratory movements. Another ganglion, C, is connected with the thick fleshy part on which the animal crawls, and which is called its foot. Near the sides of the œsophagus, *e*, are situated two other ganglia, A, A, the nerves of which are distributed to the sensitive tentacula which guard the mouth. These two *cephalic* ganglia, or ganglia of the head, evidently correspond to the brain of higher animals, being the instruments of *sensation* and *voluntary* power; and they exert a controlling direction over the movements of the animal, while the *pedal* and *branchial* ganglia (those of the foot and of respiration) minister to the *reflex* actions of the organs supplied by them.

240. In animals of higher orders, the ganglia are more numerous, as the variety of functions to be performed becomes greater; and in proportion as we ascend the scale, the cephalic ganglia become more and more developed, and more and more elevated above the œsophagus, until they finally meet on the central line above it, and, in the more perfect animals, take their place in the top of the head, overlooking, as it were, all the other organs.

241. The nervous system of Insects, whose actions are generally energetic and rapid, and in which the apparatus of movement (wings and legs) is highly developed, presents a marked difference from that of the Mollusca, which are usually inert and sluggish. It consists of a large ganglion in the head, analogous to the brain of vertebrated animals, and a chain of ganglia, one for each segment of the body, united by a double cord, as in fig. 41. In the larva or caterpillar, before it is changed into the perfect insect, the nerves arising from the ganglia are chiefly distributed to the muscles of the legs, and the ganglia are only repetitions of each other, and are of nearly uniform size; but, in the perfect insect, the wings and legs, which constitute the apparatus of locomotion, are confined to the thorax, and the segments of the abdomen have no legs. Accordingly, the ganglia of the thorax, in the perfect insect, are found to be very much increased in size, and sometimes concentrated in one mass, while those of the abdomen are much smaller.

Fig. 41—Nervous System of an Insect.

242. This difference is shown in fig. 42 (page 43), where A represents the nervous system of the caterpillar from which is produced a species of Sphinx or hawk-moth; and B, that of the moth itself. In B, the cephalic ganglion is much larger than that of A, since it has become connected with more perfect eyes and other organs of sense. The ganglia which supply the wings and legs (those next below that of the head) are also greatly enlarged and concentrated, while the abdominal ganglia are diminished, and some of them are wanting. The whole chain is also considerably shortened, the body of the moth not being as long as that of the caterpillar.

243. The chain of ganglia in insects is found to consist of two distinct *tracts*. One is composed of nerve-fibres only, and passes from the cephalic ganglion over the surface of all the other ganglia, giving

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§ 234. Describe the mode in which sensation and movement are produced through the nerves. 235. How do the movements concerned in organic life differ from those of animal life?—What are such movements called, and why? 236. What farther remarks are made in regard to centres of sensation and of reflex action? 237. What is said of the importance of studying the nervous system in various animals? 238. Describe the nervous system of the Ascidia, and the phenomena of life exhibited by that animal.

§ 239. Describe the nervous system of the Pecten.—Explain fig. 40.—What is said of the cephalic, pedal, and branchial ganglia? 240. What is said of the progressive development of the ganglia, especially those of the head? 241. Describe the nervous system of insects. —How does the nervous system of the caterpillar differ from that of the perfect insect, and what is the reason for this difference? 242. Explain this difference farther, by referring to fig. 42. 243. Explain the arrangement of the ganglia in insects, and why the motions of a headless insect may be performed without sensation.

PLATE VI.

THE BRAIN AND SPINAL CORD.

FIGURE 1.——POSTERIOR VIEW OF THE BRAIN AND SPINAL CORD,

ISOLATED FROM THE SKELETON.

a, b, Right and left hemispheres of the brain, the left hemisphere covered by the arachnoid and pia-mater; the right hemisphere naked, displaying the convolutions *c, d,* Right and left lobes of the cerebellum. *e,* The medulla oblongata. *f, f,* The spinal cord, covered by the pia-mater on the right side, and showing the origins of the spinal nerves on the left. At *f, f,* are seen the two enlargements of the cord, in the neck and the loins. *g* to *g,* The eight cervical pairs of nerves. *h* to *h,* The twelve dorsal pairs; *i* to *i,* The five lumbar pairs; *k, k,* The six sacral pairs. *l,* Lateral column of the cord. *m,* Posterior column (§ 251).

FIGURE 2.——A SECTION OF THE BRAIN AND SPINAL CORD,

INCLOSED IN THE SKULL AND VERTEBRAL COLUMN.

a, The cerebrum. *b,* The cerebellum. *c, c,* The spinal cord.—The vertebræ are cut through, so as to display a lateral view of the cord.

FIGURE 3.——THE CEREBELLUM.

A, Anterior view. *B,* Posterior view.

FIGURE 4.——BASE OF THE BRAIN.

In this figure are shown the vessels of the brain, with their complicated windings, and also the origins of some of the cerebral nerves. *a, a,* The anterior lobes of the cerebrum. *b, b,* The middle lobes. *c, c,* The posterior lobes, the left one being nearly covered by the cerebellum; the right one exposed by the removal of a portion of the cerebellum. *d,* The cerebellum. *e,* The medulla oblongata. *f, f,* &c., Arteries and veins. *g, g,* &c., Origins of nerves.

FIGURE 5.——A HORIZONTAL SECTION OF THE BRAIN,

SHOWING ITS INTERIOR.

a, a, &c., The cineritious or gray substance at the outside of the brain, following the convolutions. *b, b,* The white or medullary substance at the inside of the brain. *c, c,* The lateral and middle ventricles.

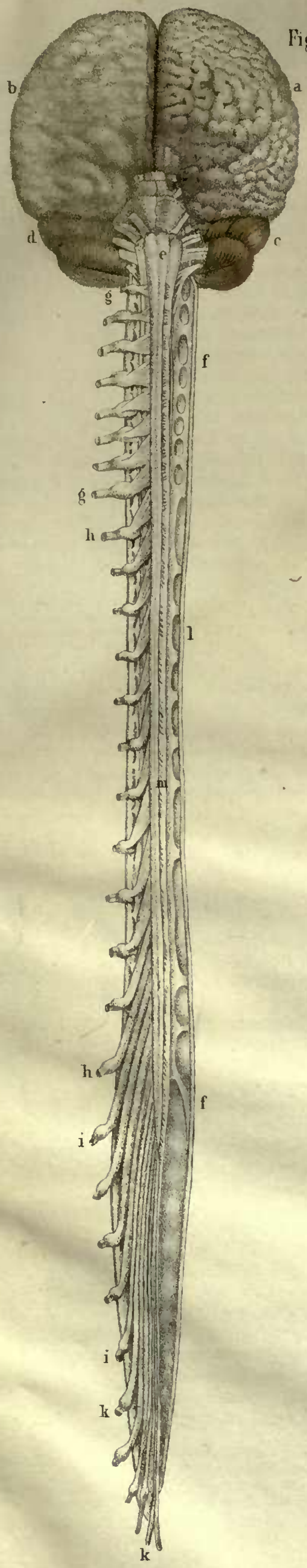
FIGURE 6.——A VERTICAL SECTION OF THE BRAIN (§262),

SHOWING THE ORIGINS OF ITS NERVES.

a, a, The cerebrum, with its convolutions. *b,* The cerebellum, displaying the arbor-vitæ upon its section. *c,* The medulla oblongata. *d,* The corpus callosum, a band of fibres which connects the two hemispheres of the brain. *e,* The eye. *f,* The first pair of nerves. *g,* The second pair. *h,* The third pair. *i,* The fourth pair. *j,* The fifth pair. *k,* The sixth pair. *l,* The seventh pair. *m,* The eighth pair. *n,* The ninth pair. *o,* The tenth pair. *p,* The eleventh pair. *q,* The twelfth pair. *r,* Spinal nerves.

PRINCIPLES OF PHYSIOLOGY. BRAIN AND SPINAL CORD.

Fig. 1.



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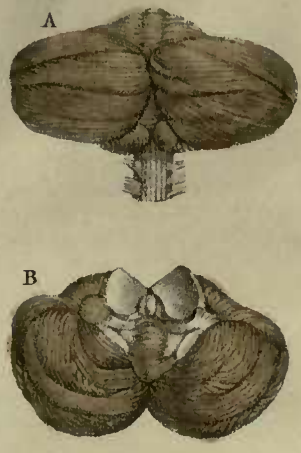

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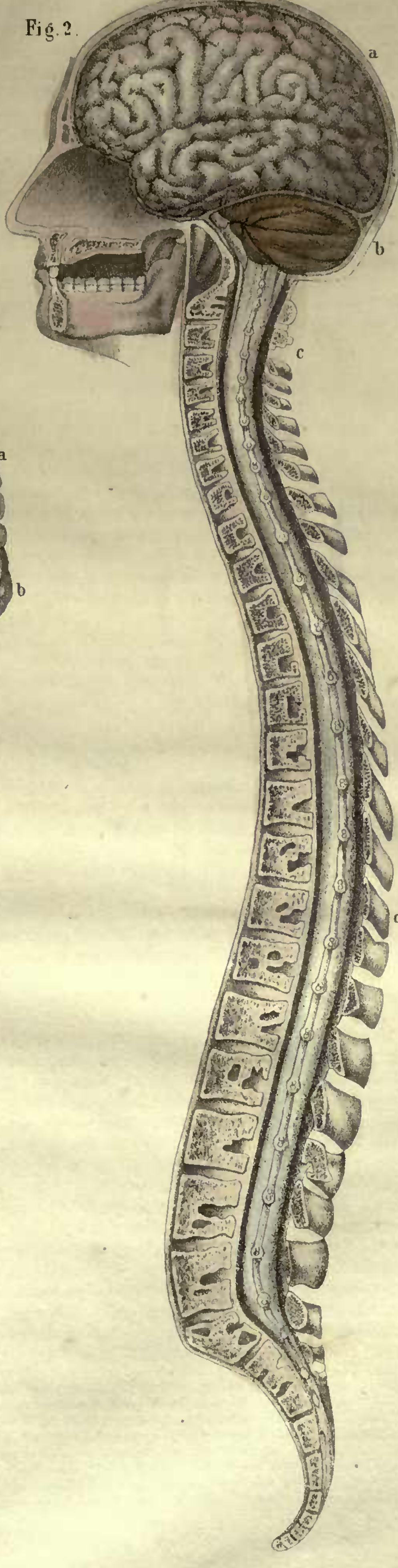

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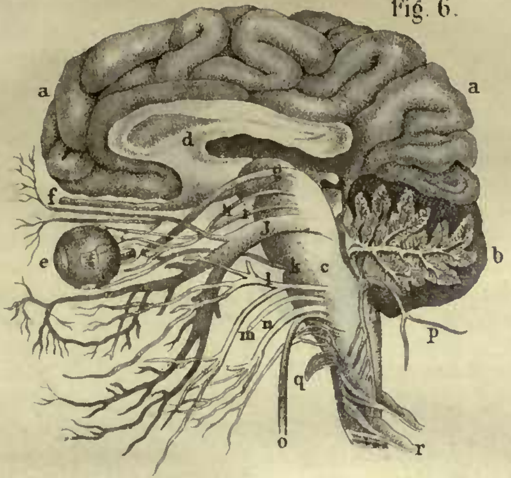

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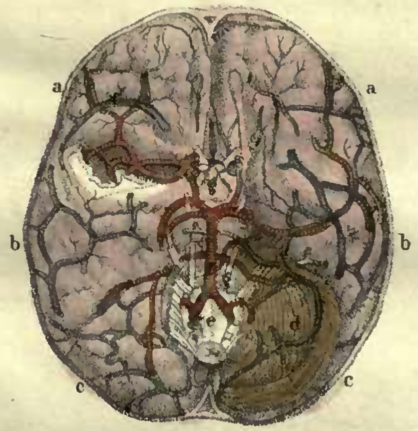

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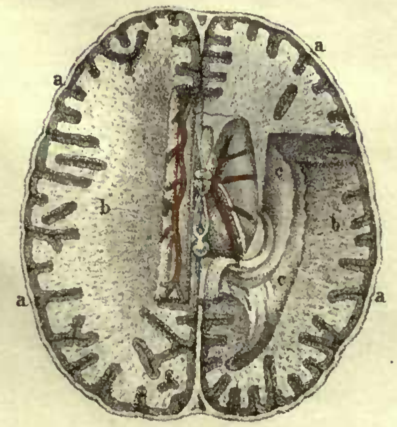

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branches to the nerves which proceed from each; while the other tract connects the ganglia themselves. Thus each segment of the insect has a distinct nervous connexion with its own ganglion, and a sympathetic connexion with the others, extending to the cephalic ganglion, which seems to have a controlling influence over all the rest, and alone to possess the faculty of sensation. Hence the motions produced by the ganglia of the trunk, when the head of the insect is removed, although they may *seem* to indicate sensation, are found to be only *reflex* in their nature—a certain irritation producing a certain movement, without choice, and probably without consciousness on the part of the animal.

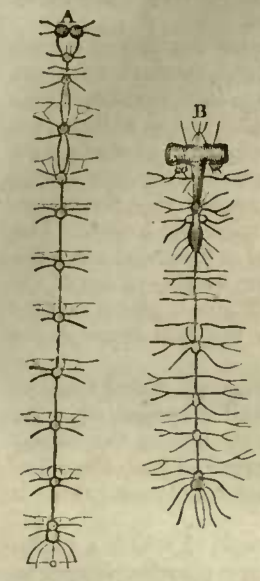

Fig. 42.—Nervous System of Sphinx-ligustri.—A, that of the caterpillar; B, that of the perfect insect.

244. Thus, if the head of a Centipede be cut off, while it is in motion, the body will continue to move as before; or, if the body be divided as many times as it has segments, each portion will still continue to move; but all consciousness seems to be lost; for if the decapitated body come in contact with an obstacle equal to its own height, it remains fixed against it, the legs moving as before, but without change of direction, or the ability of surmounting the obstacle—being no longer subject to the will of the animal, but performing reflex movements by the influence of their own ganglia.

245. In Vertebrated animals (those which possess a back-bone or spinal column), the ganglia are no longer scattered through the body, but are united into one continuous mass; and this mass, constituting the *brain* and *spinal cord*, is inclosed within the skull and vertebral column in such a manner as to be protected from the injuries to which it would otherwise be liable. The brain, in the higher Vertebrata, consists of a principal mass, called the *cerebrum*, which occupies all the front and upper part of the skull, and is divided into two *hemispheres*, or halves, by a membranous partition, running from back to front; and of a smaller mass, called the *cerebellum*, situated beneath the cerebrum, at the back part of the skull. At the base of the cerebrum are two ganglia, the olfactive and the optic, which belong to the nerves of smell and sight. All these parts in the human brain will be particularly described.

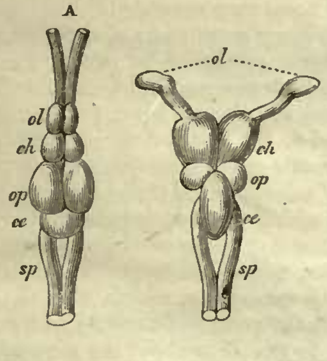

Fig. 43.—A, brain of a cod; B, brain of the shark; *ol*, olfactory ganglia; *sp*, spinal cord.

246. In the brain of a Fish, fig. 43, the parts just mentioned are beginning to acquire considerable development. The cerebral hemispheres, *ch*, the optic ganglia, *op*, the cerebellum, *ce*, are plainly to be distinguished, and their relative sizes are in proportion to the intelligence of the animal. Thus the ganglia which control the sense of sight are very large, since this sense is possessed, in a very high degree, by fishes; while the cerebral hemispheres, to which belong more especially the manifestations of will and thought, are correspondingly smaller. The cerebellum, also, which, as we shall see, is connected with the powers of motion, is large, as we should expect to find it, in animals possessed of the power of rapid movement; and is larger in the active and rapacious shark than in the less energetic cod. The spinal cord is large, and is divided at the top, so as to form an opening between its two halves. In man, as we shall see, this opening becomes entirely closed.

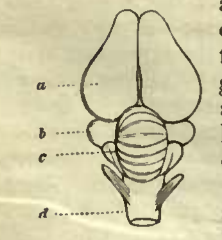

Fig. 44.—Brain of a Bird.

247. In birds, the brain has made a considerable advance towards what it finally becomes in man. The cerebral hemispheres, *a*, fig. 44, are greatly increased in size, and cover in the olfactory ganglia entirely, and the optic ganglia, *b*, partly. The cerebellum, *c*, is also much more developed, as we should expect from the variety of movements performed by birds, but is as yet undivided into lobes. The spinal cord, *d*, is still of considerable size, and is much enlarged at the points from which originate the nerves of the wings and legs.

As might be inferred from these improvements in the structure of the brain, the intelligence of birds is vastly superior to that of the animals previously considered; and they are the first in the ascending scale which are capable of education or training. Did the limits of this work permit, we might thus go on to trace the progressive development of the brain through individual species of birds and mammalia, and to show at each step a corresponding advance in intelligence, as we approximate to man.

248. In man, the cerebral developments are greatly increased, while the spinal cord is diminished in size. The surface of the brain is not smooth, but divided by furrows into a series of *convolutions*, by which the surface over which the blood comes in relation with the nervous matter is greatly increased, thus adding to the activity of the organ. The two hemispheres are more closely connected with each other by fibres running across from each side. The cerebellum is also divided into two hemispheres.

NERVOUS SYSTEM OF MAN.

249. The Nervous System of Man, and of the higher animals, consists of two portions, the *cerebro-spinal*, and the *sympathetic* or *ganglionic*. The Cerebro-spinal System is composed of the brain and spinal cord, with the nerves which proceed from them to the skin and muscles. It has been called the *nervous system of animal life*, because it is that by which sensations are received, and voluntary motions executed, and with which the *mind* is more immediately connected. The Sympathetic System is connected with the nutritive processes alone, and, from its influence over the organs of the thorax and abdomen, has been called the *nervous system of organic life*. It consists of a chain of ganglia, communicating with each other by nervous cords, extending from the head along each side of the back-bone. Nerves proceed from it to the organs of digestion and secretion, and to the heart and blood-vessels.

CEREBRO-SPINAL NERVOUS SYSTEM.—SPINAL CORD.

250. The spinal cord is a long, irregularly cylindrical column of nerve-substance, surrounded by a membranous envelop, and inclosed within a bony canal formed by the vertebræ or pieces of the back-bone. It extends from the head to the first or second vertebra of the loins, and is composed of both white and gray nervous matter. The white matter constitutes its greater portion, and is situated externally, while the gray matter occupies its central part. The spinal cord consists of two symmetrical halves united in the middle line by a set of converging fibres, called a *commissure*, but separated anteriorly and posteriorly by a vertical *fissure;* the posterior fissure being deeper, but less wide and distinct, than the anterior. Each lateral half is marked by two longitudinal furrows, which divide it into three columns or tracts, called *anterior*, *lateral*, and *posterior*. There is a considerable enlargement of the cord, in the lower part of the neck, at the part from which arise the large nerves which supply the upper extremities; and a similar enlargement is also found in the loins, at the origin of the nerves which go to the lower extremities.

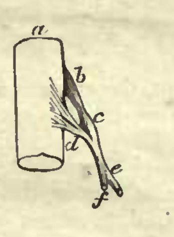

Fig. 46.—Portion of the Spinal Cord, showing the origin of the nerves.—*a*, spinal cord; *b*, posterior root; *c*, ganglion; *d*, anterior root; *e*, trunk formed by both; *f*, branch.

251. The number of nerves given off by the spinal cord, is thirty-one on each side: eight pairs in the region of the neck; twelve in that of the back, corresponding to the twelve pairs of ribs; five in the loins, and six in the pelvis. Each of these nerves arises by two distinct roots, one springing from the *anterior* column, and the other from the *posterior* column of the cord, as in fig. 46—a pair of roots on each side, corresponding to each vertebra. These roots (the posterior ones having

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§ 244. How is it shown, in the case of the Centipede, that consciousness depends on the cephalic ganglia? 245. How are the ganglia united in Vertebrated animals?—Describe the brain and spinal cord. 246. Explain fig. 42.—Describe the progressive development of the brain in fishes. 247. Describe the further advances of the brain in birds.

§ 248. How does the brain of man differ from that of the other animals already mentioned? 249. Of what two portions does the nervous system of man and the higher animals consist?—Of what is the Cerebro-spinal System composed?—What has it been called, and why?—What is the Sympathetic System?—What has it been called, and why? 250. Describe the spinal cord.—Refer to plate 6, fig. 1, and point out its parts. 251. What are the number and divisions of the spinal nerves?—Describe their mode of origin.—Explain fig. 46, and refer to plate 7.—What is the character of the fibres which spring from the posterior roots?—of those which spring from the anterior roots?—How is this proved?

first formed a ganglion), soon unite into a single trunk, which thus combines the properties possessed by both. The *posterior* set of roots consists exclusively of those fibres which convey impressions *to* the spinal cord and brain, and thus form the nerves of sensation; while the *anterior* roots consist of fibres which convey nervous influence *from* the brain and spinal cord to the muscles, and form the nerves of *motion*. Thus, if the spinal cord of an animal be laid bare, and the *posterior* set of roots be touched, acute *pain* is obviously produced; while, if the anterior roots be irritated, violent *motions* of the muscles supplied by the injured nerve are occasioned.

252. At its upper part the spinal cord becomes greatly enlarged, and forms a bulb-shaped body, called the *Medulla oblongata*, which is inclosed within the skull, and through which the connexion between the spinal cord and the brain is preserved. Its columns are continuous with those of the spinal cord, but are more prominent, and it contains a larger proportion of gray matter. It is connected with the nerves of respiration, mastication, and deglutition, and may be considered as the common centre of the cerebro-spinal system.

THE BRAIN.

253. The present description of the brain will be necessarily confined to those points which are of most importance in gaining a general idea of its structure. A full description of all its minute and complicated parts would be useless and embarrassing to the student who is not considerably advanced in anatomical knowledge.

254. The Human Brain, as already mentioned, consists of two principal portions, the *Cerebrum* or large brain, and the *Cerebellum* or small brain, protected by their membranes, and inclosed within the cranium or skull. The cerebrum, which constitutes nearly seven-eighths of the whole mass, occupies all the upper and anterior portions of the cranium, and is divided into two hemispheres or lateral halves. These are connected by transverse bands or commissures of nervous matter, and each hemisphere has three prominent masses or *lobes;* one at the forehead, one at the temples, and one at the back of the head. Its surface is intersected by deep fissures and eminences, which produce those winding inequalities called *convolutions*.

255. The nervous tissue of the cerebrum is composed of the white and gray substances already mentioned (§ 226), but disposed in a peculiar manner; a layer of the gray substance occupies the surface, and follows all the irregularities of the convolutions; while the white substance is placed in the central parts. Thus, each convolution consists of a layer of gray substance at the outside, and of white substance within. The manner in which the two substances are thus arranged to form the convolutions, may be rudely illustrated, by taking two pieces of cloth, laying one upon the other, and collecting them up in folds into a globular shape. By such an arrangement, the surface over which the blood comes in contact with the nervous matter is greatly increased; and it is interesting to know that, in man, the convolutions are more numerous and extensive, and the depressions between them deeper, than in any other animal. The brain is most abundantly supplied with blood, the amount sent to it having been estimated as high as one-fifth of that contained in the whole body, though one-tenth would be probably nearer the truth.

256. Towards the centre and base of the cerebrum, the surface is inflected inward, so as to form an intricate internal cavity, the several compartments of which are called *ventricles*. They communicate with each other, and serve still farther to increase the cerebral surfaces. It is in these ventricles that collections of serous fluid take place, in cases of what is called dropsy of the brain, or water in the head.

257. The *cerebellum* is situated at the back of the head, below the cerebrum. It is divided into two lateral lobes, and instead of waving convolutions, its surface presents a great number of plaits, with furrows between them. It is composed, like the cerebrum, of gray and white matter, and the white matter presents, on a vertical section of one of the lobes, a tree-like appearance, called *arbor vitæ* (tree of life).

The different parts of the spinal cord and brain are represented in plate 6, which is to be referred to and studied in connexion with this chapter.

258. The membranes which surround and protect the brain are three in number, and are called the *Dura mater*, the *Pia mater*, and the *Arachnoid*. These membranes are also prolonged downwards, so as to form a tubular sheath to the spinal cord. The dura mater (hard mother) was so called by the old anatomists, because they supposed it to be the origin or mother of all the hard, firm membranes of the body, and the pia mater (tender mother) was also thus named by them as being the origin of the soft membranes.

259. The *Dura mater* is a strong, dense, fibrous membrane, which forms the external envelop of the brain, and is in contact with the bones of the skull, to which it strongly adheres. It is separated into two layers, the internal of which is doubled on itself so as to form two remarkable processes. The one, from its resemblance, in shape, to a sickle, is called *falx cerebri*, and is interposed between the two hemispheres of the brain, so that when the head rests on one side, the uppermost hemisphere is prevented from pressing upon the lower. The other process is called *tentorium cerebelli*, and is extended over the cerebellum, so as to prevent the pressure of the cerebrum upon the latter, when the head is in an erect position. There is also a smaller process, called *falx cerebelli*, which separates the two hemispheres of the cerebellum.

260. The *Arachnoid* (spider's web) membrane, so called from its extreme thinness, lies beneath the dura mater, and is spread over the entire surface of the brain. It corresponds in its use to the serous membranes of the heart and other organs, and serves to keep the opposite surfaces of the dura mater and the pia mater, between which it lies, moist and smooth.

261. The *Pia mater* is a loose, transparent web, in which a multitude of blood-vessels cross each other in every possible direction. Minute branches of these vessels, in immense numbers, penetrate the brain, to which they afford nutriment, at the same time that they serve as a means of attachment between the brain and the membrane. The pia mater follows all the convolutions and enters all the cavities of the brain, and is also prolonged over the spinal cord and the nerves, constituting one of the most important membranes of the body.

262. Twelve pairs of nerves spring from the brain, and are named as follows: 1st pair, *Olfactory nerves;* 2d, *Optic nerves;* 3d, *Motores oculorum;* 4th, *Patheticus;* 5th, *Trifacial nerves;* 6th, *Abducentes;* 7th, *Portio dura*, or *facial nerve;* 8th, *Portio mollis*, or *auditory nerve;* 9th, *Glosso-pharyngeal nerve;* 10th, *Pneumo-gastric nerve;* 11th, *Hypo-glossal nerve;* 12th, *Spinal accessory nerve.*

263. The first pair is distributed to the inner membrane of the nose, and transmits to the brain the impression produced by odors; the second pair is distributed to the retina of the eyes, and in like manner conveys the impression of sight; the third, fourth, and sixth pairs are nerves of motion only, and are distributed to the muscles which move the eyes. The fifth pair is for the most part a nerve of sensation only. It divides into three branches; the first of which, called the *ophthalmic nerve*, passes into the orbit or cavity in which the eye is lodged, and is then distributed in the forehead and temples; the second branch, or *superior maxillary*, supplies the cheeks, nose, and upper lip, with sensitive filaments; the third, or *inferior maxillary*, which, like the spinal nerves, has also a motor root, gives the power of moving to the masticating muscles, and gives sensibility to the parts about the mouth.

264. The seventh pair is the general motor nerve of the muscles of the face; the eighth pair is the nerve of hearing, and is distributed to the internal ear; the ninth pair supplies the back of the mouth and pharynx, and is concerned in the act of swallowing; the tenth pair originates from the medulla oblongata, and supplies the lungs and air-passages, as also the heart and stomach; the eleventh pair gives motion to the tongue; the twelfth pair is concerned in respiration. All these nerves are supposed to contain two sets of filaments—one communicating with the cerebral hemispheres, and the other with the spinal cord. Plate 6, fig. 6, represents a section of the brain, showing the arrangement of these nerves, That of the nerves proceeding from the spinal cord is seen in plate 7, fig 1.

§ 252. Describe the medulla oblongata.—With what nerves is it connected.—Refer to plate 6, and point it out. 253, 254. Of what two principal portions does the brain consist?—Explain the position, divisions, &c., of the cerebrum, and point them out in plate, 6.——255. How are the gray and white nervous substances disposed in the cerebrum?—How may the formation of the convolutions be illustrated?—What is the effect of this arrangement?—What is said of the quantity of blood sent to the brain? 256. Describe the ventricles of the brain, and refer to them in the plate. 257. Describe the position and structure of the cerebellum.

§ 258. What are the membranes of the brain?—Why were the dura and pia mater so called? 259. Describe the dura mater.—What are its processes called, and what are their uses? 260. Why is the arachnoid so called?—What is its use and position? 261. Describe the structure of the pia mater, and its mode of attachment to the brain. 262. How many pairs of nerves spring from the brain?—What are they called? 263. What are the distribution and offices of the six first pairs? 264. What of the six last pairs?—What two sets of filaments do these nerves contain?—Refer to plate 6, fig. 6, and point out these nerves.

FUNCTIONS OF THE CEREBRO-SPINAL SYSTEM IN MAN.—OF THE SPINAL CORD.

265. Some fibres of the nerves which pass off from the spinal cord terminate in its central gray matter, while others are continued through its outer white substance to the brain. The first set of fibres constitutes, properly, the *spinal* portion of these nerves, and the second, the *cerebral* portion; and it is not to be doubted that, although united in the same sheath, the two sets are as distinct as if they were separately distributed. The cerebral fibres carry impressions *to* the brain, where they are felt as *sensations;* and by other fibres of the *same nerves*, which pass from the brain to the muscles, the *muscles* are acted upon by the *will*, and *voluntary* motion is produced.

266. But the brain is not at all times in a state of activity. During sleep, for instance, it is completely torpid, and ordinary consciousness is entirely gone. Yet all those movements which are necessary to life go on as usual; the breathing continues—liquid poured into the mouth is swallowed—the body changes its position. The same things take place in an animal whose cerebrum has been *removed*. A pigeon, for example, has been kept alive for several months in that condition; running, when pushed; flying, when thrown into the air; drinking, when its beak was plunged in water; swallowing food, when placed in its mouth; but at all other times, when left to itself, appearing in a profound sleep.

267. From these facts, it is evident that the brain is not to be regarded as the *only* centre of nervous power, nor as *essential* to the life of the body, and that the spinal cord must possess a great degree of independent power. This power differs from that of the brain, chiefly in the fact that it is exerted without the concurrence of the *judgment* and *will;* and the movements produced by it are rather like those of an automaton, set in motion by pulling certain wires, or touching certain springs. Thus the motions of a decapitated animal are never *spontaneous*, but are always *excited* by a stimulus of some kind.

268. As to the question whether these motions can take place without any *feeling* or *sensation*, the better opinion seems to be, that they *do not depend upon sensation*, but upon a property peculiar to the spinal cord, by which certain impressions *necessarily* excite motions of an involuntary character. This seems to be nearly proved by the fact, that such motions take place not only when the brain has been removed, and the spinal-cord has been left entire, but even when the spinal-cord has itself been cut into several portions. Thus, if the head of a frog be cut off, and the spinal cord divided in the middle, so that the fore-legs remain connected with the upper part, and the hind-legs with the lower, each pair of legs will separately move when irritated, but the two pairs will not act together, as they do when the spinal cord is undivided. Or, when the spinal cord has been divided, without removal of the brain, the upper limbs remain under the control of sensation, judgment, or will, while the lower may be *excited* to movement, though they are completely paralyzed to the will. Similar phenomena have been evinced in cases of injury to the spinal cord in man.

269. A good example of this *reflex* function of the spinal cord is also found in the act of deglutition. When any substance reaches the back part of the throat, there is an involuntary effort to swallow, caused by irritation of the glosso-pharyngeal nerve, which is conveyed to the spinal cord, and the muscles concerned in the act of swallowing are excited by a returning influence through the pneumo-gastric nerve. In the same manner it is supposed that different portions of the bowels are excited to contract and force along their contents. Thus the mind is relieved from any effort of will, so far as the operation of many important organs is concerned, and nature carries on its work unseen and unfelt. Were it otherwise, it is to be feared that many persons would waste their lives in anxious watching of the processes of digestion and nutrition.

§265. What are the two different sets of fibres found in the nerves of the spinal cord?—How do they terminate? how are they united? and what is the operation of the cerebral fibres? —266. What is said of the continuance of life when the brain is torpid, and when it has been removed? 267. What is made evident by these facts?—How does the power of the spinal-cord differ from that of the brain?—What do the movements produced by it resemble? —268. Do such movements depend upon sensation?—How is it proved that they do not? 269. What is an example of the reflex action of the spinal cord?—What is farther said on this subject?

FUNCTIONS OF THE MEDULLA OBLONGATA.

270. The medulla oblongata differs from the rest of the spinal cord in its functions, mainly in the importance and extent of the actions governed by it. Like the cord, it is a *conductor* of nervous impressions; but it has a wider extent of function, since all impressions which pass to and fro from the brain and spinal cord must be transmitted through it. Motor impressions are transmitted through its anterior columns and sensitive impressions through its posterior columns. Thus, if one of its anterior columns be divided, the animal will lose the power of motion in one-half the body, while its sensation will remain unimpaired.

271. The functions of the medulla oblongata, as a nervous centre, are more immediately important to the maintenance of life than those of any other part of the system. The nervous force necessary for deglutition and respiration is generated in this organ. It has been proved by repeated experiments, that the entire brain may be cut away, in successive portions, and life yet continue for a considerable period, and the respiratory movements be uninterrupted. Life may also continue when the spinal cord is in like manner cut away from below upward as high as the phrenic nerve, which commences in the throat. In some of the Amphibia (tortoises, frogs, &c.), the brain and spinal cord have both been thus removed, and still respiration and life continued, so long as the medulla oblongata was untouched. But a very slight wound at its central portion will produce suffocation and sudden death.

272. The power of reflection is more apparent in this than in any other portion of the nervous centres. By this power the respiratory movements are carried on. Thus the application of stimuli to many parts of the body, the nerves of which transmit impressions to the medulla, will cause respiratory movements, by reflection through the nerves which proceed from the medulla to the muscles concerned in respiration. This accounts for the "catching for breath" produced by dashing cold water in the face. *Convulsive* movements are also produced through the agency of this part of the cord. In those convulsions which result from the teething of children, in lock-jaw, and other like diseases, death usually ensues through suffocation, the muscles of respiration becoming so fixed that the air cannot be breathed.

FUNCTIONS OF THE CEREBELLUM.

273. Much discussion has taken place in regard to the functions of the cerebellum. It seems to be now agreed, however, by the most intelligent physiologists, that it is the organ which is more especially connected with *motion*. Numerous experiments have been made on living animals, all of which go to show that, after the removal of the cerebellum, the power of executing those movements necessary to locomotion, is lost. The faculties of volition and sensation remain, but the power to walk, fly, or even stand, is uniformly lost, from the inability to combine the action of the muscles in groups.

274. From facts of this character, it seems to be most probable that the function of the cerebellum is to harmonize and regulate the actions of the voluntary muscles. In accordance with this theory, we find that those animals which possess variety of motions, or muscular actions, in the highest degree, are endowed with a cerebellum correspondingly large.

In animals of the cat tribe, which use their limbs for seizing their prey, and which are capable of great muscular exertion, the cerebellum is larger than in those whose limbs are subservient to locomotion only. In birds, the variety of whose movements is still greater, it is larger than in most of the mammalia. It acquires its highest development in man; as might be expected, from the muscular combinations necessary to maintain the erect position, and to perform the intricate and varied movements of the human hand.

The influence of each half of the cerebellum is directed to muscles on the opposite side of the body, and it would appear that, for the right ordering of movements, the actions of its two halves must be always mutually balanced and adjusted.

§270, 271. Explain the functions of the medulla oblongata.—What has been proved by experiment? 272. What is said of the power of reflection in the medulla? 273. Explain the functions of the cerebellum.—What experiments are mentioned? 274. What deduction is drawn from such facts?—What is said of the size of the cerebellum in cats, birds, &c., and of the direction of its influence?

FUNCTIONS OF THE CEREBRUM.

275. The cerebrum is the organ through which the phenomena of thought and intelligence are manifested. By its means, we *reason* upon the ideas excited by sensations, we judge and decide upon our course of action, and put that decision into practice, by issuing a mandate which is conveyed by the nervous trunks to the muscles.

276. It is a common, but erroneous idea, that *reason* is peculiar to man; and that the actions of the lower classes of animals are due to instinct alone. There can be no doubt that reasoning processes, exactly resembling those of man, are performed by many animals; such, for instance, as the dog, the horse, and the elephant. We must admit that an animal reasons, when it profits by experience, and obviously adapts its actions to the end it desires to gain, especially when it departs from its natural instincts to do this. The presence of intelligence is also perceived in the differences of character found in various individuals of the same species. Thus, some dogs are stupid, others sagacious, some ill-tempered, others good-tempered; just as there are stupid men and intelligent men, ill-tempered men and good-tempered men. But the actions of insects seem to be wholly instinctive; so that we observe no difference of temper or capacity in them.

277. Birds, however, which resemble insects in many of their instinctive tendencies, exhibit a remarkable distinction in their actions. In escaping from danger, in obtaining food, and in constructing their habitations, the actions of birds, like those of insects, are instinctive. But, in adapting their operations to peculiar circumstances, birds display a variety and fertility of resource not to be found in insects. Birds also learn by experience, and may be educated; while insects observe perfect uniformity in all their actions.

278. The relative amount of intelligence in different animals bears a pretty constant proportion to the size and developments of the cerebral hemispheres. Size alone, however, does not produce all the difference. In ascending from the lower to the higher animals, a marked advance in the complexity of the brain is observed. The convolutions become more and more prominent, giving a proportionally increased surface for the entrance of the blood-vessels, and an equally increased amount of the gray matter, which seems to be the real centre of all the operations of the organ. Still, the size of the cerebrum, compared with that of the spinal cord and the ganglia at its top, usually affords a tolerably correct measure of the intelligence of the animal. The same rule holds good in comparing different men, if due allowance be made for the comparative activity of their general functions, or, in other words, for their differences in *temperament*.

279. Thus, two men, whose brains are of the same size, may differ widely in mental vigor, because the general system of one performs its functions more actively and energetically than that of the other. For the same reason, a man of small brain, but whose general habit is active, may have a more powerful intellect than another of much larger brain, but whose system is sluggish and inert. But of two men alike in temperament, and having the same general configuration of head, it cannot be doubted that the one with the larger brain will surpass the other. It is a striking fact, that almost all those persons who have been eminent for their acquirements, or for the influence of their talents over their fellow-men, have had large brains. This was the case, for example, with Newton, Byron, Cuvier, Cromwell, and Napoleon. The average weight of the brain is about three pounds two ounces. That of Cuvier weighed four pounds eleven and one-half ounces; and those of Byron and Cromwell are said (though the fact is doubtful) to have weighed nearly six pounds. In idiots, on the contrary, the brain is usually very small, in some instances weighing only one and one-half pounds.

280. The size of the brain may be pretty correctly estimated by the *facial angle*. This angle is obtained by drawing a horizontal line (*c d*, figs. 46 and 47) from the entrance of the ear to the floor of the cavity of the nose; and a second line (*a b*) from the most prominent part of the forehead to the front of the upper jaw, so as to intersect the other. This line will evidently be more inclined to the former, and the angle formed by the two will be more acute, in proportion as the face is more projecting and the forehead more retreating; while it will be nearer a right angle, if the forehead be prominent, and the muzzle project but little. Hence the facial angle will indicate the proportion which the brain bears to the face.

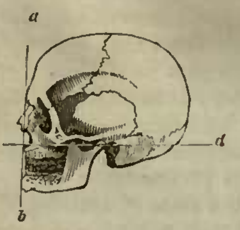


Fig. 46.—SKULL OF EUROPEAN.

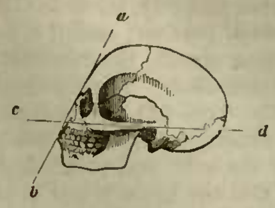


Fig. 47.—SKULL OF NEGRO.

281. This angle is more open in man than in any other animal, and it varies greatly in the various races of men. The difference between the facial angle of the European and American head, and that of the negro, is seen in figs. 46 and 47. In the one it is about 80°, and in the other about 70°. In monkeys, it varies from about 65° to 30°, and as we descend still lower, it becomes still more acute.

CONNEXION OF THE MIND WITH THE BODY.

282. The brain, as appears from what has already been said, is the connecting link between the mind and the body. All the organs of the body may be said to be the agents of the mind, inasmuch as the mind manifests itself through them all. Thus the hand, the eye, the muscles which control the features, are all made to express more or less forcibly the varied emotions of the mind. The mind, too, controls, to a certain extent, the operations of the various functions of the body, to which it gives a shape and form in correspondence with itself.

283. In this view, we may regard the entire body as an assemblage of organs for the manifestation of mind. But the influence of the mind upon the body is reciprocated by that of the body upon the mind. If the body can be made to suffer from the condition of the mind, the mind itself is not less affected by the condition of the body. A single illustration will suffice to show this fact. Melancholy or depression of spirits, from any cause whatever, will often produce disease or derangement of the liver; and, on the other hand, a derangement of the liver will almost always induce melancholy, though no other cause exists.

284. But the intellect is not limited, in its influence, to the organic and animal functions; it also stamps itself upon every lineament and feature of the man. Thus, as we ascend in the scale of being, intelligence, as it becomes more highly developed, is marked by a more perfect organization of the brain and nervous system. The nervous power in man is at its highest point, as is shown by the very liability to disease or derangement of the vital functions, arising from the sympathy between the physical and intellectual powers. The mere animal has no desires to gratify but those of appetite. These satiated, he has no anxiety for the future, no repinings for the past; he is not wasted by care nor harassed by toil and disappointment. Man, on the contrary, is the constant subject of exciting and depressing influences—of functional and organic derangements, growing out of his complex nature. Ever restless, never satisfied, he is constantly on the rack of physical and mental torture. He consequently obtains the highest perfection and excellence, when he obeys most perfectly the laws of his nature, and retains the physical and the intellectual in the most complete harmony of development and action.

285. Hence in the education of the young, the powers of the body and the mind should be cultivated together. The mind should not be excited to such a degree as to overtask the brain, nor so neglected as to leave the latter without a proper degree of exercise. One extreme

§ 275. What are the functions of the cerebrum? 276. Is reason peculiar to man?—What is said of the reasoning powers of animals?—How is the presence of intelligence indicated? 277. What is said of the difference, in respect to intelligence, between birds and insects? 278. What is said of the relative proportion between the amount of intelligence and the size and conformation of the cerebrum? 279. Why do men, having brains of the same size, differ in intellectual power?—What other facts does the same reason account for?—Of two men alike in temperament, which will surpass the other?—What class of persons have had large brains?—What instances are given? 280. How may the size of the brain be estimated?—How is the facial angle formed, and how does it indicate the proportion which the brain bears to the face?

§ 281. What is said of the difference of this angle in different races? 282, 283. What is said of the brain, as connecting mind and body?—What of the mutual effect of mind and body?—What is the illustration? 284. What is said of the nervous power of man, compared with that of the animal?—How is this difference shown? 285. What inferences are drawn from the preceding sections?—What is said of "precocious children?"

PLATE VII.

THE NERVES.

FIGURE 1.——POSTERIOR VIEW OF THE PRINCIPAL NERVES.

The general arrangement of the nervous centres and the distribution of the nervous trunks, are shown in this figure.—The spinal column is laid open, so as to display the cord, with the nerves which pass from it. The muscles of the left side and limbs are dissected, to show the course of the principal nerves.

a, The hemispheres of the cerebrum. *b*, The lobes of the cerebellum. *c*, The spinal cord. *d*, The facial nerve, the principal motor nerve of the face. *e*, The brachial plexus, a net-work of nerves, originating by several roots from the spinal cord, and going to supply the arm.—From this plexus proceed *f*, the scapular nerve; *g*, the median nerve; *h*, the ulnar nerve; *i*, the musculo-spiral nerve; *j*, the intercosto-humeral (nerve of Wrisberg). From the spinal cord proceed the intercostal nerves, *k*, *k*, running between the ribs; the nerves forming the lumbar plexus, *l*, from which the front of the leg is supplied; those forming the sacral plexus, *m*, which supplies the back of the leg. The chief branch of the sacral plexus is the great sciatic nerve, *n*, which divides into the tibial nerve, *o*, the peroneal or fibular nerve, *p*, and many other branches. The nerves seen on the right side of the figure, are the ramifications of the sub-cutaneous nerves, branching beneath the skin, in which they are finally lost. Some of the superficial veins are also represented.

FIGURE 2.——PRIMITIVE NERVE TUBULES (§227),

GREATLY MAGNIFIED.

a, A perfectly fresh tubule, with a single dark outline. *b*, A tubule or fibre, examined some time after death, showing a double outline, in consequence of the coagulation of the fluid contained in the tube; the outer line being that of the sheath of the fibre; the inner, that of the margin of the coagulated contents. *c*, The changes produced by death still farther advanced, and causing a varicose or beaded appearance. *d*, A tubule or fibre, the central part of which, in consequence of still farther changes, has accumulated in separate portions within the sheath.

FIGURE 3.——A PACINIAN CORPUSCLE,

HIGHLY MAGNIFIED.

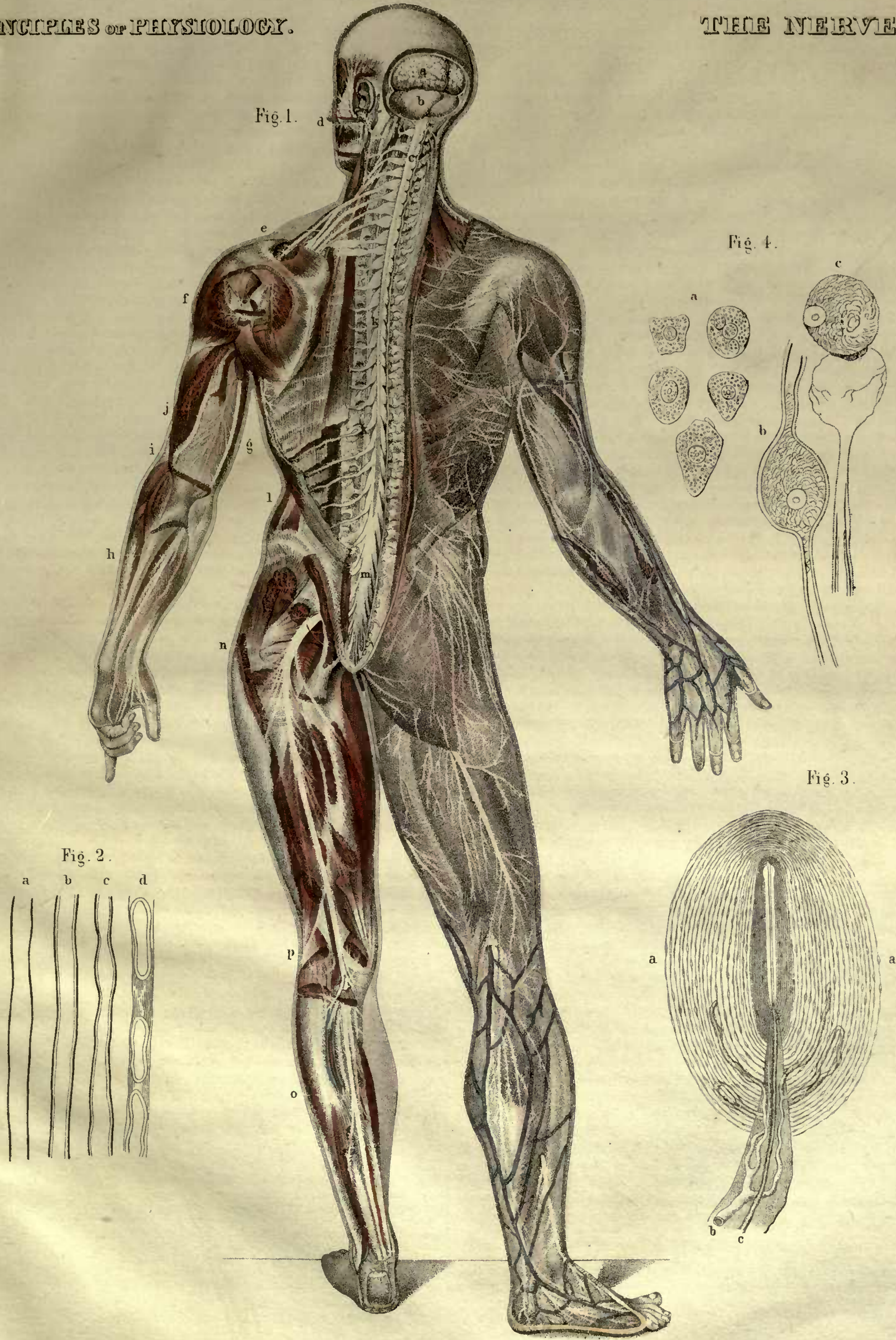
These corpuscles are little elongated, oval bodies, in which some one of the nerves terminate. They are named after their discoverer, Pacini, and are situated on many of the cutaneous nerves of the hands and feet. Each corpuscle is formed of several concentric layers of fine membrane, with intervening spaces containing fluid. *a*, *a*, The corpuscle, with its concentric membranes. *b*, A minute artery, ending in capillaries, which form loops in the spaces between the membranes. *c*, A nerve-tubule, proceeding to the central cavity of the corpuscle, where it loses its white substance.

FIGURE 4.——NERVE CORPUSCLES OR VESICLES,

Of which the gray or vesicular nerve-substance (§231) is composed.—They are large cells, filled with a finely granular material. *a*, Vesicles from a ganglion, highly magnified. *b*, The mode in which the vesicles are connected with the nerve-fibres.—The dilated sheath of the nerve-fibre forms a capsule around the vesicle. *c*, A nerve corpuscle, escaped by pressure from the capsule formed around it by the dilated sheath of the nerve-tubule.

PRINCIPLES OF PHYSIOLOGY.

THE NERVES.



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wastes the vital energies, while yet immature; the other degrades heaven-born powers to a level with the brute. The injudicious course, so often pursued, of stimulating the intellect of what is called "a precocious child," too often results in misery to the sufferer itself, and in disappointment to its unwise friends. Such children rarely fulfill the promise of their earliest years, and the anxious parent usually sees the brilliancy of their youth fade into dullness and disease in after life.

286. Not much less injurious is the mere training of the body without a suitable exercise of the intellect. The mind must have occupation as well as the body. Just as the muscles increase in strength and firmness, by a proper degree of constant and regular exertion of their powers, so does the mind expand and improve by a healthy and sound action of the brain. Of the whole train of nervous diseases, there is none more dreadful than those which result from a lack of some absorbing mental pursuit. Those persons who "have nothing to do," are the most miserable of mortals. By nothing interested or amused—with no high aim, no grand object in life—they squander, in the most frivolous and superficial diversions, that existence which was given them for nobler and more exalted purposes. Let the fashionable idler think of Brummel in his mad-house and his filth, and be warned.

287. But the importance of mental culture is apt also to be forgotten by a better and worthier class. The Farmer, the Merchant, the Mechanic, are too liable to confine their attention simply to their routine of daily labor. They do not always think of the happiness produced by a cultivated and enlightened mind, or even of the advantage which such a mind gives them over others in their own vocations. The most successful men in any business, or even in any profession, have not been those who have exerted themselves to know only what is necessary to that one calling. Most great merchants have had a knowledge of other books besides their Ledgers—of other sciences besides that of their Interest tables. Elihu Burritt is none the worse blacksmith because he speaks ten languages; nor Talfourd the worse lawyer because he wrote "Ion." These are extreme instances, to be sure, and men seldom *excel* in more than one pursuit; but yet a *general* cultivation of the mental powers is none the less essential to complete success in any thing.

288. On the other hand, he who over-taxes his brain with long-continued and unvarying mental exertion in any one pursuit, is sure to find the tone of his mind become relaxed, the energies of his frame paralyzed; and he fails of success through the very means which he takes to secure it. Thus *variety* is a necessary ingredient in well-disciplined mental effort. When the attention becomes fatigued, and the mind refuses to act with clearness and precision, as often happens in a favorite and absorbing occupation, change should be immediately resorted to. The mind should be withdrawn from the exciting topic, and applied to another.

289. It has hitherto been, and probably always will be, impossible to determine the mode in which the mental principle operates in its connexion with the brain. But it appears that *one* of the cerebral hemispheres is sufficient for all operations of the mind, except the highest intellectual acts; for numerous cases have occurred where no loss of mental vigor ensued, though one hemisphere of the cerebrum was so injured or disorganized as to be incapable of performing its functions. The remaining hemisphere, in these cases, was sufficient to perform the office of both: but the mind does not seem, in any of these cases, to have been tested in very high intellectual exercises; so that it is not certain that one hemisphere will suffice for these.

290. In ordinary sensation and effort of the will, the impressions are carried across from one hemisphere to the other; so that, if either hemisphere be injured, the effects produced, whether in loss of sensation or of voluntary motion, are observed on the side of the body opposite to that on which the injury to the brain is received. Thus, if the *left* lobe of the optic nerve be divided, the sight of the *right* eye will be lost.

291. Most physiologists are of opinion that each mental faculty has a special portion of the brain appropriated to it as its proper organ. The evidence in support of this opinion is too lengthy to be introduced here. It may be found in the works of phrenologists, who have so adapted and illustrated it, that the theory of a plurality of organs in the cerebrum is often regarded as peculiar to phrenology, and as so essentially connected with it, that this theory cannot be maintained, unless that system is true. "But it is plain, that all the system of phrenology built upon the theory may be false, and the theory itself may be true; for the schools of Gall and Spurzheim assume not only this theory, but also that they have determined all the primitive faculties of which the mind consists; that is, all the faculties to which special organs must be assigned, and the places of all those organs in the cerebral hemispheres and cerebellum. Possibly this may be a system of error, founded on a true theory: the cerebrum may have many organs, and the mind as many faculties; but what are the faculties which require separate organs, and where those organs are, may be subjects of which only the first or most general knowledge is yet attained."

292. The brain has been called the organ of the mind; but this must be taken with some restriction. There is little doubt of the truth that the brain *is* the organ of those parts of the mind which have to do with the things of *sense;* but it is by no means certain that the cerebral hemispheres, or any other parts of the brain, are, "in any meaning of the term, the *organs* of those parts or powers of the mind which are occupied with things *above* the senses. The Reason or Spirit of man which has knowledge of divine truths, and the conscience, with its natural discernment of right and wrong, cannot be proved to have any connexion with the brain. In the complex life we live, they are, indeed, often exercised in questions in which the intellect, or some other lower mental faculty is also concerned; and, in all such cases, men's actions are determined as good or bad, according to the degree in which they are guided by the higher or by the lower faculties. But the reason and the conscience must be exercised independently of the brain, when they are engaged in the contemplation of things which have not been learned through the senses, or through any intellectual consideration of sensible things. All that a man feels in himself, and can observe in others, of the subjects in which his reason and his conscience are most naturally engaged; of the mode in which they are exercised, and the disturbance to which they are liable by the perceptions or ideas of sensible things; of the manner and sources of their instruction; of their natural superiority and supremacy over all the other faculties of the mind; and of his consciousness of responsibility for their use: all teach him that these faculties are wholly different, not in degree only, nor as different members of one order, but in kind and very nature, from all else of which he is composed; all, if rightly considered, must incline him to receive and hold fast the clearer truth which Revelation has given of the nature and destinies of the Spirit to which these, his highest faculties, belong."

293. And it is here that we are most forcibly impressed with the superiority of man over all other created things. His reason and his conscience, apart from any other faculties, naturally induce in him the belief in some unseen but powerful Being, whose favor he seeks, whose anger he deprecates, and whose spiritual existence he desires to share. "This desire, which seems to have been implanted by the Creator in the mind of man, is one of the chief natural arguments for the immortality of the soul, since it could scarcely be supposed that such a desire should have been implanted by our beneficent Maker, if it were not in some way to be gratified. By the Immortal Soul, the existence of which is thus guessed by man, * * * he is connected with beings of a higher order, among whom Intelligence exists, unrestrained in its exercise by the imperfections of the bodily frame, with which it is here connected, and by which it here operates."

294. "Such views tend to show us the true nobility of Man's rational and moral nature; and the mode in which he may most effectually fulfill the ends for which his Creator designed him. We learn from them the evil of yielding to those merely animal tendencies—those 'fleshly lusts which war against the soul'—that are characteristic of beings so far below him in the scale of existence, and tend to degrade him to their level; and the dignity of those pursuits which, by exercising his intellect, and by expanding and strengthening his loftier moral feelings, raise him towards beings of a higher and purer

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§ 286. What is said of bodily training without the exercise of intellect?—What of those who "have nothing to do?" 287. What is said of the importance of mental culture in men of business? 288. What is said of the necessity of variety in mental effort? 289. Is it known how the mind is connected with the brain?—Are *both* cerebral hemispheres necessary to the operations of the mind?—How is this proved?—Is it certain that one hemisphere is sufficient for the *highest* intellectual effort? 290. What is said of the transference of sensation from one hemisphere to the other?—If the right side of the brain is injured, on which side of the body are the effects produced?—How is this illustrated in the case of the optic nerve? 291. What is said of the theory of the division of the brain into separate organs?—What of the truth of the system of phrenology as founded on this theory?

§ 292. What remarks are made concerning the connexion of Reason and Conscience with the brain?—When must these faculties be exercised independently of the brain?—To what should man be inclined by these considerations? 293, 294. Repeat the remarks made in application of this subject to the Immortality of the Soul and a Spiritual existence.

order. But even the loftiest powers and highest aspirations of which he is at present capable, may be regarded as but the germs or rudiments of those more exalted faculties which the human mind shall possess, when, purified from the dross of earthly passions, and expanded into the comprehension of the whole scheme of Creation, the soul of man shall reflect, without shade or diminution, the full effulgence of the Love and Power of its Maker."

CHAPTER XI.

SENSATION AND THE SENSES.

295. There are two kinds of sensation, named common and special. *Common* or *general sensation* is the consequence of that sensibility which exists in nearly every part of the body, and is manifested whenever any part is touched or stimulated. It is by this that we feel those impressions made upon our bodies by the objects around us, or by actions taking place within, which produce the various modifications of pain, the sense of *contact* or *resistance*, the sense of variations of *temperature*, and others of a similar character.

296. Since impressions made upon the sensory nerves are dependent upon the action of the blood-vessels (§ 232, 233), it is obvious that no parts destitute of the latter can receive such impressions, or, in common language, can possess sensibility. Accordingly we find that the hair, nails, teeth, cartilages, bones, and other parts whose substance contains few or no vessels, are either completely incapable of receiving painful impressions, or are possessed of a very dull sensibility to them. On the other hand, the skin, and other parts, which usually receive such impressions, are abundantly furnished with blood-vessels.

297. It does not necessarily follow, however, that parts should be sensible in a degree proportioned to the amount of blood they contain; since this blood may be sent to them for other purposes. Thus, it is a condition necessary to the action of muscles, that they should be copiously supplied with blood; but they are not acutely sensible; and glands, also, the substance of which has very little sensibility, receive a large amount of blood for their peculiar purposes.

298. Besides this common sensibility, there are certain parts of the body which are capable of receiving impressions of a peculiar or *special* kind, such as sounds or odors; and the sensation produced by these is called *special sensation.* The varieties of this sensation are perceived by the five senses, *Touch*, *Taste*, *Smell*, *Hearing*, and *Sight.* The nerves which convey these special impressions are not able to receive those of a common kind; thus the eye, however well fitted for seeing, would not feel the touch of the finger, if it were not supplied with branches from the Fifth pair, as well as by the optic nerve. Nor can any nerve of special sensation be affected by impressions that are adapted to operate on another; thus the ear cannot distinguish the slightest difference between a luminous and a dark object; nor can the eye distinguish a sounding body from a silent one, except by *seeing* its vibrations.

SENSE OF TOUCH.

299. By the sense of Touch is usually understood that modification of the *common sensibility* of the body, of which the surface of the skin is the especial seat. In some animals, as in Man, nearly the whole exterior of the body is endowed with it, in no inconsiderable degree; but in others, as in most Birds and Reptiles, and many Fishes, the greater part of the body is so covered by hairs, scales, or bony plates, as to be nearly insensible; and the faculty is restricted to particular portions of the surface, which often possess it in a very high degree. The sensory impressions, by which we receive the sensation of touch, are made by the objects themselves upon the nerves which are distributed to the skin (§ 206).

300. The especial organ of touch in Man, is the hand, which is peculiarly fitted for this purpose by the great sensibility of its skin, especially at the extremities of the fingers, the variety of movements of which it is capable, the power of opposing the thumb to the rest of the hand, and the flexibility of the fingers. In most other Mammalia, the lips and tongue are employed as the chief organs of touch; in the Elephant, this sense is evidently possessed very acutely by the little finger-like projection at the end of its trunk; and in the Bat, it seems to be diffused over the whole membrane of which the wings are formed. It has been found that bats, when deprived of sight, and, as far as possible, of hearing and smelling also, still flew about with equal certainty and safety, avoiding every obstacle, flying through passages only just large enough to admit them, avoiding threads stretched in every direction across the apartment, and passing through places previously unknown, with the most unerring accuracy. Hence some naturalists were inclined to attribute to the bat the possession of a sixth sense unknown to man. All these facts can be accounted for, however, on the supposition that the wings of the bat possess a high degree of sensibility in their delicate membrane, which receives impressions from the pulses of the air, produced by the act of flying, and modified by the neighborhood of solid bodies.

301. The only idea communicated to our minds by the sense of Touch, when this is exercised in its simplest form, is that of *resistance;* and we cannot form a notion of the size or shape of an object, nor of the nature of its surface, by *feeling* it, unless we *move* the object over our hand or other sensory organ, or the latter over the former. By the various degrees of resistance which we encounter, we estimate the hardness or softness of the body; and by the impressions made upon the papillæ (§ 206), when they are moved over its surface, we form an idea of its smoothness or roughness. It is by attention to the muscular movements we execute, in passing our hands or fingers over its surface, that we acquire our ideas of its size and figure; and hence we perceive that the sense of touch, without the power of moving the tactile organ over the object, would have been of comparatively little use.

302. This sense is capable of improvement to a remarkable degree; as we see in persons who have become more dependent upon it, in consequence of the loss of their sight. This doubtless results, in part, from the increased attention which is given to the sensations; and, partly from the greater acuteness or impressibility of the organ itself, arising from the use of it. Of the wonderful delicacy reached by this sense, from its cultivation by the blind, many singular instances are recorded.

303. The sense of *temperature* is of a different character from the common sensation of touch; and either may be lost, without the other being affected. It is rather of a *comparative* than a *positive* kind; that is, we form our estimate of temperature rather by comparing it with that to which our body (or that part of it employed to test the heat or cold) has been previously exposed, than by the knowledge which we derive through the sensation, of the *actual* degree of heat or cold to which the organ is exposed. Thus, if we plunge one hand into a basin of hot water, and the other into cold, and then transfer both hands to a basin of tepid water, this will feel cold to the hand which has been previously accustomed to the heat, and warm to the other.

304. In the same manner, the temperature of the city of Quito, which is situated half way up a lofty mountain, one of the Andes, is felt to be chilly by a person who has ascended from the burning plains below, while it seems intensely hot to another who has descended from the snow-capped summit above; the residents in the town at the same time regarding it as moderate—neither hot nor cold. It is a curious circumstance, that a weak impression made on a large surface seems more powerful than a stronger impression made upon a small surface;

§ 295. What are the two kinds of sensation?—What is common sensation?—What impressions are felt by this kind of sensation? 296, 297. What is said of the blood-vessels as connected with sensibility?—Are all parts, however, sensible in proportion to the amount of blood they contain?—What is said of the muscles and glands in this connexion? 298. What is special sensation?—How are the varieties of this sensation perceived?—What are the names of the senses?—Can the nerves which convey *special* impressions also receive *common* impressions?—How is this illustrated in the case of the eye?—Can any nerve of special sensation receive an impression adapted to operate on another nerve of the same kind?—How is this illustrated? 299. What is understood by the sense of Touch?—What parts of the body possess this sense in man?—In other animals?—How are the impressions made by which the sensation of touch is received?

§ 300. What is the especial organ of touch in Man?—How is the hand fitted for this purpose?—What are the chief organs of touch in other Mammalia?—What in the Elephant?—What is said of the sense of touch in the Bat? 301. What is the first idea communicated by this sense?—How must we form a notion of the size and shape of an object?—How of its roughness or smonthness?—Why would this sense be imperfect without the power of moving the organ of touch? 302. What is said of the improvement of this sense?—From what does this improvement result? 303. How does the sense of temperature differ from the common sensation of touch?—How do we form an estimate of temperature?—What illustration is given? 304. As another illustration, what is said of the temperature of Quito?—How does extent of surface affect the power of an impression?—What fact does this account for?

thus, if the fore-finger of one hand be immersed in water at 104°, and the whole of the other hand be plunged in water at 102°, the cooler water will be thought the warmer; whence the well-known fact, that water, in which a finger can be held, will scald the whole hand.

305. Besides the hand, the lips and tongue also are delicate instruments of touch, and are probably the first employed for that purpose. Thus, an infant, having learned, by application to its mother's breast, to receive and cultivate impressions of touch in the lips and tongue, continues for some time to rely with greater confidence on the evidence obtained from this, than from any other source, and accordingly persists in carrying every object to its mouth, in order to test it, until its hands and fingers become sufficiently educated and manageable to serve as substitutes.

306. In most insects, the special organs of touch are prolongations from the portion of the head near the mouth. These are called *antennæ* or feelers; they are often of great length, and present an extraordinary variety in their forms, usually contain a great number of joints, and are very flexible. This flexibility enables them to be turned towards any object which the insect wishes to examine; and when it is walking, we see them constantly applied to the surfaces of the bodies which it approaches, in a manner which leaves no doubt that they are used as organs of touch, just as a blind man uses a stick in feeling his way. By the antennæ, also, insects communicate with each other. Almost every person must have observed the action of these organs, where two bees meet each other out of their hive. They seem to reconnoitre one another for some time, by moving their antennæ; and often keep up these movements for a considerable period, as if carrying on a close conversation.

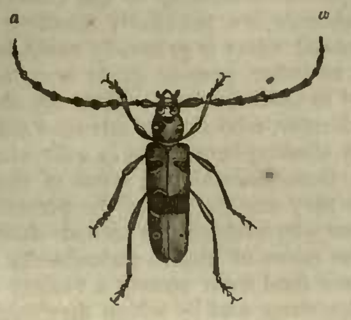

Fig. 49.—Capricorn Beetle.—*a*, *a*, antennæ.

SENSE OF TASTE.

307. The sense of taste, like that of touch, is excited by the direct contact of particular substances with certain parts of the body; but it is of a much more refined nature than touch; inasmuch as it communicates to us a knowledge of properties which that sense would not reveal to us. All substances, however, do not make an impression upon the organ of taste. Some have a strong savor, others a slight one, and others, again, are altogether insipid. The cause of these differences is not understood; but it may be remarked, that, in general, bodies which cannot be dissolved in water have no savor, but that most of those which are soluble have a more or less strong taste. Their solubility, in fact, seems to be one of the conditions requisite for their action on the organ of taste; for, when that organ is completely dry, it does not receive any sensation from solid bodies brought into contact with it, though the same bodies may have the most powerful taste, if reduced to a fluid form.

308. The chief purpose of the sense of taste is to direct animals in the choice of their food, and hence its organ is always placed at the entrance of the digestive canal. In higher animals, the tongue is the principal seat of taste; but the lips, the inside of the cheeks, and the upper part of the throat, are also capable of receiving the impressions of certain savors. The mucous membrane which covers the tongue is copiously supplied with blood-vessels, and is thickly set, especially upon its upper surface, and towards the tip, with *papillæ*, resembling in structure those of the skin, but larger. Pl. 8. fig. 3.

309. The tongue itself is made up of muscular substance, which accomplishes the various movements required in the acts of mastication, and in the production of articulate sounds. It is supplied with nerves from the third division of the fifth pair, from the glosso-pharyngeal, and from the hypo-glossal. The last is the motor nerve of the tongue; the first is the one chiefly concerned in the conveyance of sensory impressions from the front and sides of the tongue; and the other (the glosso-pharyngeal) seems to have for its office the conveyance of those impressions from the back of the tongue which excite the muscles of swallowing to action, as well as those which produce the sensation of nausea, and excite the act of vomiting. The papillæ are, for the most part, if not entirely, supplied from the fifth pair; and the branch of this pair which proceeds to the tongue, is known as the *lingual nerve.* When the papillæ are called into action by the contact of substances having a pleasant savor, they become dilated and lengthened, and rise up from the surface of the mucous membrane. In this manner is produced the roughness which is felt on the surface of the tongue, or the inside of the cheek, when a piece of sugar has lain there for awhile.

310. The tongue presents nearly the same structure among the mammalia, in general, as in man; but, in birds, it is usually cartilaginous or horny in its texture, and destitute of nervous papillæ; so that their sense of taste cannot be very acute. Several of them use their tongues for other purposes; the wood-pecker, for instance, whose tongue is sharp and barbed, transfixes insects with it, and the parrot uses it to keep steady the nut or seed which is being crushed between the mandibles. In some reptiles, the tongue is large and fleshy; in others, as the serpent tribe, it is slender and forked, and possessed of great quickness of motion. In the frog and chameleon, it serves as an organ of prehension, and is darted out with great rapidity to catch the insect-food of the animal. The tongue of fishes is generally in a mere rudimentary state, and is fixed in the throat, and often covered with teeth. The tongue of the bee forms a little tube, through which it draws up the juices of flowers.

311. A most important function of the sense of taste is that of directing animals in the choice of their food. Most of the lower animals will instinctively reject articles of food that would be pernicious to them. Even the voracious monkey will seldom touch poisonous fruits, though their taste be agreeable; and animals, whose digestive apparatus is adapted to one kind of food, will reject all others. As a general rule, it may be stated that substances, the taste of which is agreeable to us, are useful and wholesome articles of food, and that those which are nauseous and disgusting are injurious. But there are many signal exceptions to this rule; as, for instance, both the taste and smell of Prussic acid are very agreeable, and yet it is one of the most deadly of known poisons.

312. Much of the perfection of the sense of taste is often due to the sapid substance being also possessed of odor, and exciting the simultaneous action of the sense of smell. Of this, any one may convince himself, by closing the nostrils, and breathing through the mouth only, while holding in the mouth, or even rubbing between the tongue and the palate, some aromatic substance; when its taste will be scarcely recognized, though it is immediately perceived when the nasal passages are again opened, and the effluvia received into them. Frequent and continued repetition of the same taste renders the perception of it less and less distinct, just as a color becomes more and more dull and indistinct, the longer the eye is fixed upon it. This is exemplified in the foolish experiment, sometimes practised, of giving a person, blindfolded, brandy, rum, gin, or several different kinds of wines, in rapid succession. In a short time, the most experienced taster becomes entirely incapable of distinguishing between the liquors.

313. No sense is more influenced by habit, than taste. Many substances that are exceedingly disgusting at first, finally become not only less repugnant, but even highly grateful to the taste. Fashion, or necessity, may at first have been the cause of their being taken; but habit causes them to be eagerly sought after. Innumerable instances of these acquired tastes are observed in all ages, in every country, and in every state of society. Thus, the most celebrated sauce of antiquity was made from the half-putrid intestines of fish; a rotten egg, especially if it contains a chick, is highly esteemed among the Siamese; raw fish is devoured with great eagerness by the South Sea Islanders; and the civilized epicure prefers his game and venison in what he calls a "ripe" condition.

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§305. What other parts, besides the hand, possess delicacy of touch?—Why does an infant habitually carry objects to its mouth? 306. What are the special organs of touch in insects?—Describe the antennæ, and their uses. 307. How does the sense of taste compare with that of touch?—What is said of the differences of savor in different substances?—Is the cause of these differences known?—What class of bodies generally possess savor, and what do not?—What condition is requisite for the action of bodies on the organ of taste?—How is this shown? 308. What is the chief purpose of the sense of taste?—Where is the organ of taste always situated?—What parts are the principal seat of taste?—Describe the membrane and papillæ of the tongue. 309. Describe the structure and nerves of the tongue.—What effect have savory substances on the papillæ?

§310. What is said of the tongue of birds?—Of reptiles?—Of fishes?—Of the bee? 311. What is said of the sense of taste in connexion with the choice of food?—What general rule is stated?—What exception to this rule is mentioned? 312. What is said of the dependence of the sense of taste upon that of smell?—How may this be shown?—What is said of repetition of the same taste?—How is this exemplified? 313. What is said of the influence of habit on taste?—Give the examples of acquired tastes.

314. The susceptibility of the organs of taste to pleasurable sensations depends very much on the state of the stomach, even in health. With whatever enjoyment we partake of a favorite dish when we first sit down with a good appetite, the relish diminishes as hunger is appeased; and if, notwithstanding, we persist in eating, nausea and disgust at length supervene, and the glutton is compelled to desist. This consent subsisting between the stomach and the organ of taste is an important and wise provision, informing the individual when a sufficiency of food has been taken.

SENSE OF SMELL.

315. By the sense of smell we are enabled to perceive scents or *odors*, which are the finely divided particles of odoriferous bodies. These odorous particles must be exceedingly minute, for many substances do not seem to lose weight by freely imparting their scent to an unlimited quantity of air. Thus the experiment has been tried of keeping a grain of musk freely exposed to the air of a room, the doors and windows of which were constantly open, for a period of ten years; the air, thus continually changed, was completely impregnated with the odor of musk; and yet, at the end of that time, the particle was not found to have suffered any perceptible diminution in weight.

316. The most advantageous position of the organ of smell is evidently at the commencement of the respiratory passages; so that, by its peculiar sensibility, the air which is received into the lungs may be *tested*, as it were. In all the air-breathing Vertebrata this organ consists of a pair of cavities called the *nasal fossæ*, situated between the mouth and the orbits of the eyes. They open upon the front of the face by two orifices or *nostrils*, and into the pharynx by two other orifices. The two cavities are separated from each other by a vertical partition, situated on the middle line; their sides are formed by the various bones of the face, and by the cartilages of the nose. These cartilages are elastic, and readily admit of motion and modification of shape in the nose, while at the same time they contribute to its form, as characteristic of an individual or a race. In some animals, they are largely developed, as in the Elephant, where they form the trunk or proboscis. Several small muscles are attached to the cartilages, by which the nostrils are dilated or contracted. The nasal cartilages are represented in plate 8, fig. 5.

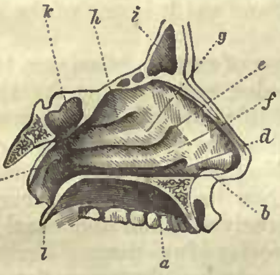

Fig. 50.—VERTICAL SECTION OF THE NASAL CAVITY.—*a*, mouth; *b*, nostril; *c*, posterior opening; *d*, *e*, passages between the spongy bones; *f*, *g*, *h*, spongy bones; *i*, frontal sinuses; *k*, sphenoidal sinuses; *l*, vail of the palate.

317. The interior of the nasal fossæ is lined by a delicate mucous membrane, the *pituitary* or *schneiderian*, on which the olfactory nerves are distributed, and the extent of this is increased, by its being folded over certain projections from the walls of each cavity, which are termed *spongy bones*. In man, these are three in number. Prolongations of this membrane are carried also into cavities hollowed out in the neighboring bones, called *sinuses* (fig. 50). The frontal sinuses, *i*, are situated between the eyebrows; and the sphenoidal sinuses, *k*, are placed farther back. There is also a large cavity excavated in the bone of the upper jaw, on either side. The membrane which lines these is kept moist by its own secretions. A vertical section across the middle of the nasal cavities, which exhibits some of these parts more clearly, is given in fig. 6, plate 8.

318. The mechanism of the sense of smell is very simple. When air, charged with odorous particles, passes over the membrane that lines the nose, some of these particles are delayed by the mucous secretion that covers it, and act upon the delicate sensory extremities of the olfactory nerve, with which it is thickly set. The highest part of the nasal cavity appears to be that which possesses the most acute sensibility to odors; and hence it is that when we snuff the air so as to direct it into the upper part of the nose, instead of allowing it to pass simply along the lower portion from the nostrils to the posterior orifices, we perceive delicate odors which would otherwise have escaped us.

319. Besides the olfactory nerve, the mucous membrane of the nose receives branches of the fifth pair. This latter nerve endows it with *common* sensibility, and also conveys the impressions produced by acid or pungent vapors, which act upon it in the same way as the corresponding fluids do upon the tongue. Vapors of this kind, such as the fumes of nitric acid, or of ammonia, are *felt* by the irritation which they produce, rather than *smelt;* and the impression they occasion gives rise to the reflex action of *sneezing*, by which they are driven from the nose. Hence sneezing will be caused by an irritating substance, such as snuff, after the olfactory nerve is divided, if the branches of the fifth pair be entire.

320. Animals do not all equally perceive the same odors. Carnivorous animals have the power of detecting most accurately, by the smell, the peculiarities of animal matters, and of tracking other animals by the scent, but have no apparent sensibility to the odors of plants and flowers. Herbivorous animals are peculiarly sensitive to the latter, but their sensibility to animal odors is generally much less acute. Some herbivorous animals, however, possess great accuracy and delicacy of smell, even in regard to animal odors. Thus the deer and antelope frequently escape the hunter, who cannot advance sufficiently near to shoot them, except by stealing upon them in a direction contrary to that of the wind. In these animals the sense of smell serves as the chief means by which they are warned of the presence of their enemies. One special purpose why herbivorous animals should possess an acute susceptibility to the odors of plants, undoubtedly is, to guide them in the selection of their food from among a variety of plants, some of which are highly deleterious, and by which they might otherwise be readily poisoned.

321. The wonderful perfection in which this sense exists in the dog is well known. The certainty with which he detects the footsteps of animals, long after they have passed—the facility with which he traces the progress of his master through crowded streets, recognizing the emanations which his foot has left, among all the diversity and multitude of odorous particles—is truly astonishing. In like manner, the deer-hound pertinaciously pursues his victim, and follows its traces through the herd of its fellows, among which it vainly seeks for protection.

322. Birds, in general, do not appear to possess the sense of smell in as great perfection as quadrupeds. It has been, indeed, supposed that vultures and other rapacious birds are guided to their prey, from immense distances, by the scent; but it is well proved, by Audubon and other naturalists, that these birds are guided by sight, and not by smell. In the case of the Fish-hawk, which suddenly turns and plunges upon its scaly victim from a great height in the air, the sense of smell cannot be supposed to give the least direction to the motions of the bird. In fishes, the nasal cavities have no communication with the gullet; the lining membrane is beautifully plaited, and abundantly covered by mucus. The sense of smell in fishes has, however, been denied by some physiologists, and it does not seem probable that they possess it in a high degree. Many insects are able to distinguish odorous substances at considerable distances. By this sense, the common flesh-fly is guided to the putrid meat on which its eggs are deposited.

323. Like all the senses, that of smell is greatly improved in acuteness by education. In the blind, especially, it becomes, next to that of touch, the sense on which they place the greatest reliance, and by which they distinguish individuals from each other. The Indians of Peru, according to Humboldt, can ascertain, by the smell, in the middle of the night, whether a visitor be an European, an American, an Indian, or a negro. Sometimes the smell becomes morbidly sensitive. There are those who shudder at the scent of cheese, or faint at that of a cat. Cloquet mentions the case of an eminent French physician, who was exceedingly annoyed, during an illness in which his smell became remarkably acute, by the odor of copper; and, after careful search, the source of his annoyance was found to be a brass pin which had fallen among the bed-clothes.

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§ 314. What is said of the connexion between the organs of taste and the stomach? 315. What do we perceive by the sense of smell?—What is said of the minuteness of odorous particles?—By what experiment is this illustrated? 316. Why should the organ of smell occupy the position which it does?—Describe the construction, divisions, &c., of the nose. 317. Describe the interior conformation of the nasal cavities, the pituitary membrane, spongy bones, sinuses, &c. 318. Explain the mechanism of the sense of smell.—Why are odors perceived more acutely when we snuff up the air?

§ 319. What is the office of the nasal branches of the fifth pair of nerves?—How is the action of sneezing produced. 320. What is said of the peculiarities of smell in different animals?—In the deer and antelope?—Why should herbivorous animals be acutely sensible to the odors of plants? 321. What is said of the delicacy of smell in the dog? 322. What of the smell of birds?—Of fishes?—Of insects? 323. How is the sense of smell improved?—What is said of this sense in the blind?—In the Indian?—What instances are given of a morbid sensitiveness of smell?

PLATE VIII.

ORGANS OF SENSE

FIGURE 1.——SPECIAL ORGANS OF TOUCH.

A, Papillæ of the skin, magnified, containing expansions of the nerves and of the capillary blood-vessels.

B, The spiral arrangement of the papillæ at the ends of the fingers, in which the sense of touch is especially seated.——(*See* Plate V.)

FIGURES 2, 3, 4.——ORGANS OF TASTE.

THE TONGUE AND SALIVARY GLANDS.

Figure 2.—*a*, The tongue. *b*, *c*, *d*, *e*, Muscles of the tongue. *f*, The parotid gland. *g*, Duct of the parotid gland, through which the saliva is poured into the mou *h*, Sub-maxillary gland. *i*, Sub-lingual gland. *j*, Vessels of the tongue. *k*, *k*, Nerves of the tongue.

THE DORSUM, OR UPPER SURFACE OF THE TONGUE.

Figure 3.—*a*, The epiglottis. *b*, The root of the tongue. *c*, *c*, Mucous glands, covering the root of the tongue. *d*, *d*, *d*, The large papillæ, arranged in two obliq lines, meeting at the middle of the root of the tongue. Spreading over the rest of the surface are seen the small papillæ, in great numbers and different shapes and sizes.

THE INFERIOR SURFACE OF THE TONGUE.

Figure 4.—This figure represents the lower side of the tongue laid open, so as to show the distribution of the nerves. *a*, The hyoid-bone, to which the base of the tong is attached. *b*, *b*, The stylo-glossus muscles, reaching from the tongue to the styloid processes of the temporal-bone, *c*, *c*. Their action is to draw t tongue backward. *d*, The hypo-glossal nerve. e, The lingual nerve.—Minute filaments of these nerves are spread throughout the tongue and in its papill

FIGURES 5, 6.——ORGAN OF SMELL:

THE NOSE AND NASAL CAVITIES.

Figure 5.—*a*, Nasal bones. *b*, Ascending processes of the superior maxillary-bone, articulating with the nasal-bone. *c*, *d*, *e*, Cartilages of the nose.

VERTICAL SECTION ACROSS THE NASAL CAVITIES.

Figure 6.—*a*, *b*, c, The superior, middle, and inferior spongy bones. *d*, The vomer, which forms the vertical partition between the cavities. *e*. Roof of the mouth.

FIGURES 7, 8.——ORGAN OF HEARING:

VERTICAL SECTION OF THE ORGAN OF HEARING.

Figure 7.—*a*, *b*, *c*, The external ear. *d*, Entrance to the auditory canal. *f*, Auditory canal. *e*, *e*, Petrous portion of the temporal-bone, in which the internal ear excavated. *g*, Membrane of the tympanum. *h*, Cavity of the tympanum, the chain of ear-bones being removed. (For the relative positions of the bones, see fig. 52, page 00.) *i*, Cells excavated in the temporal-bone. *j*, Opening from the ear-cavity into these cells.—On the side of the cavi opposite the membrana tympani, are seen the fenestra ovalis and rotunda, which open into the vestibule. *l*, The vestibule. *k*, The Eustachian tub *m*, Semi-circular canals. *n*, Cochlea. o, Auditory nerve. *p*, Canal, by which the carotid artery enters the skull. *q*, Part of the glenoid fossa, whi receives the head of the lower-jaw. *r*, Styloid process of the temporal-bone.

A MAGNIFIED REPRESENTATION OF THE LABYRINTH,

LAID OPEN SO AS TO DISPLAY ITS CAVITY.

Figure 8.—*l*, The vestibule. *n*, The cochlea. *q*, The partition by which the cochlea is divided into two parts. o, The fenestra ovalis. *p*, The fenestra rotund *r*, *r*, *r*, The semi-circular canals. *s*, Portion of the temporal-bone.

PRINCIPLES OF PHYSIOLOGY. ORGANS OF SENSE.

Fig. 4.

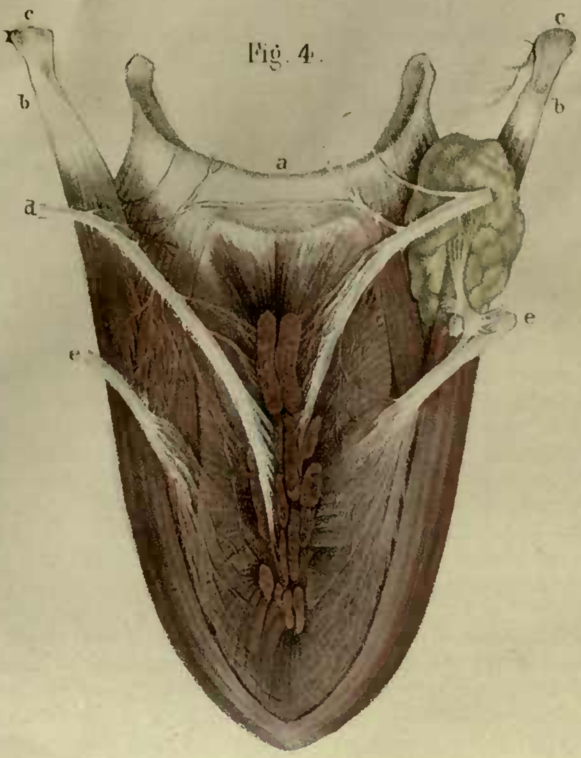


Fig. 2.

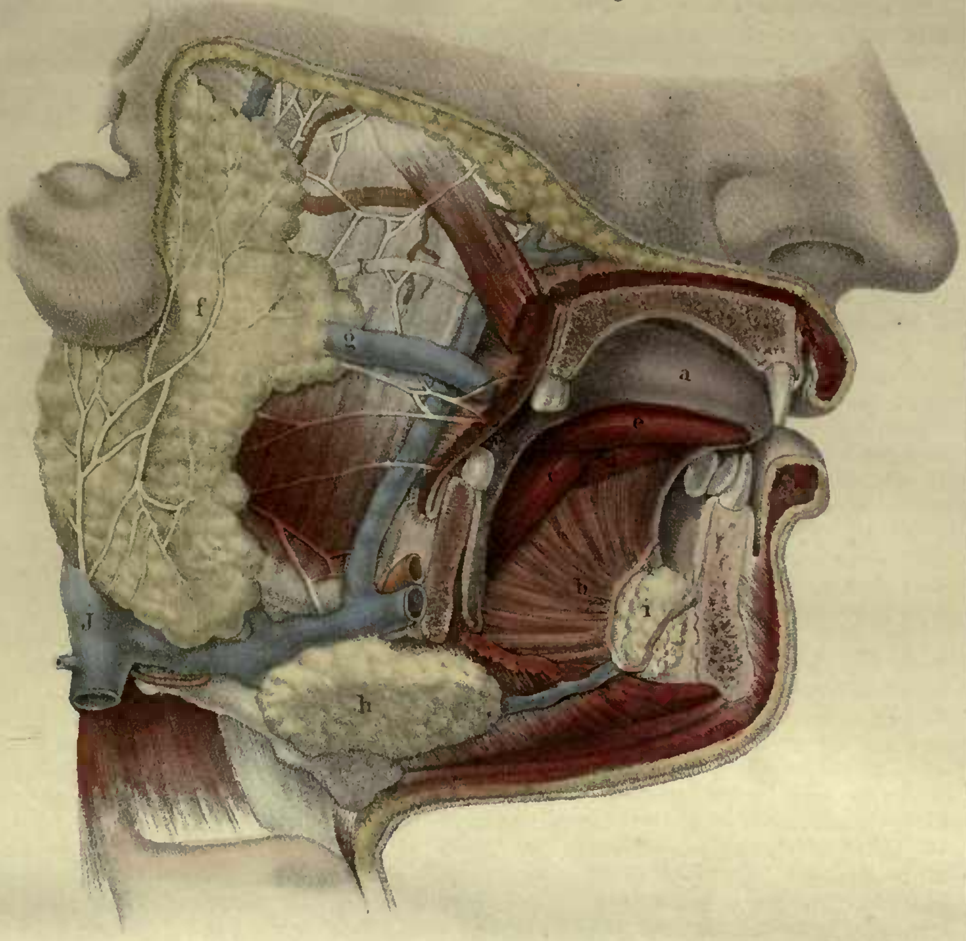


Fig. 3.

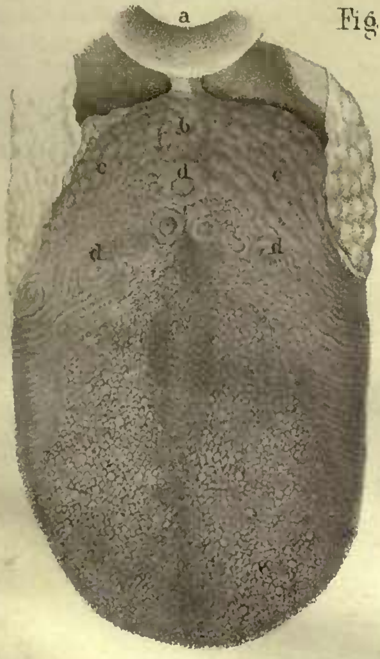


Fig. 1.

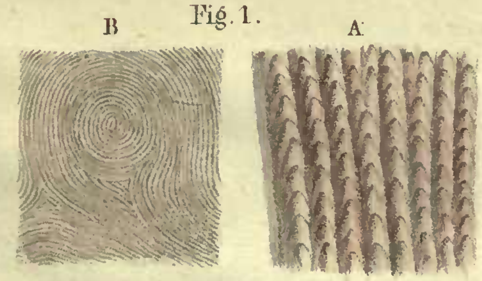


Fig. 6.

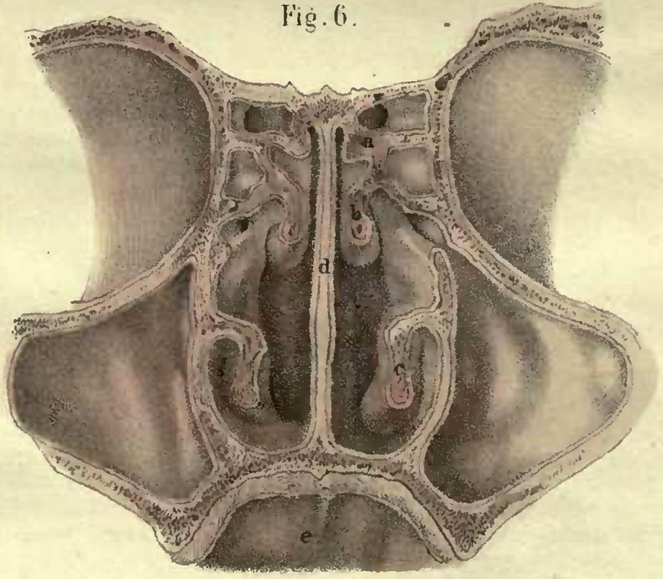


Fig. 5.

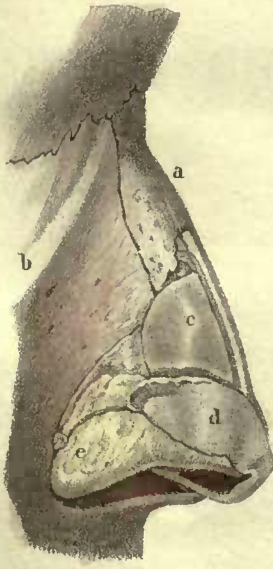


Fig. 7.

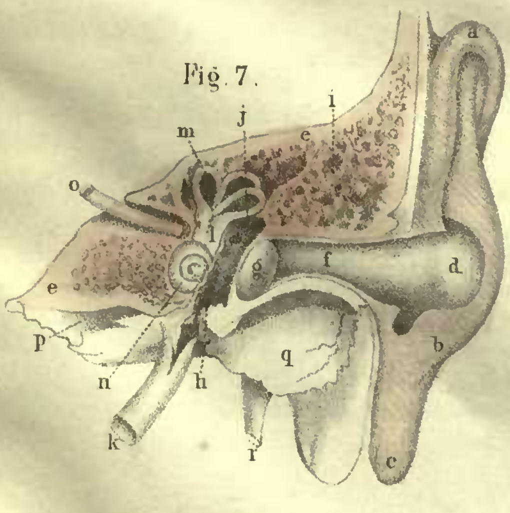
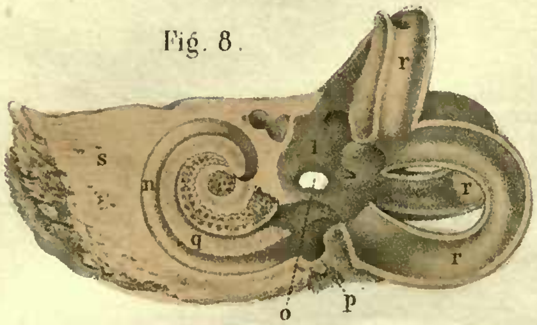


Fig. 8.



Lith of Kellogg

Entered according to Act of Congress in the year 1850 by [illegible] & Comstock, in the Clerk's Office of the District Court of Connecticut.

Hartford, Conn.

SENSE OF HEARING.

324. By this sense, we become acquainted with the sounds produced by bodies in a certain state of vibration. The vibrations of the sounding body are communicated to the air, in which they produce, in every direction, a series of undulations or waves, by which the sound is conveyed to a distance. These undulations spread more widely as they become more distant from the sounding body, just like the rippling circles produced on the surface of water when a stone is thrown into it; and, in proportion as they spread, they become less powerful. This is the reason why Sound becomes less intense, as the sounding body is more distant.

325. Although air is the usual conducting medium for the sonorous undulations, liquids or solids may answer the same purpose. Thus, if a person hold his head under water while two stones are struck together, also under water, at a considerable distance, he will hear the sound produced by the blows with extreme distinctness, and even with painful force. Or, if the ear be laid against one end of a long piece of timber, while a scratch of a pin be made, or a watch be laid, upon the other end, even the faint sounds made by them will be heard distinctly. That a medium of some kind is necessary to convey the sonorous vibrations, is proved by the fact, that, if a bell be made to ring in the receiver of an air-pump from which the air is exhausted, no sound is heard, though the ringing immediately becomes audible when the air is allowed to enter.

326. It is a fact of much importance in regard to the action of the organ of hearing, that sonorous vibrations which have been excited, and are being transmitted in a medium of one kind, are not imparted with the same readiness to others. The following conclusions have been drawn from experimental inquiries on this subject:

1. Vibrations excited in solid bodies may be transmitted to water, without much loss of their intensity; although not with the same readiness with which they would be communicated to another solid.

2. On the other hand, vibrations excited in water lose some of their intensity in being propagated to solids; but they are returned, as it were, by these solids to the liquid, so that the sound is more loudly heard in the neighborhood of the solids than it would otherwise have been.

3. The sonorous vibrations of solid bodies are much more weakened by transmission to air; and those of air make but little impression on solids.

4. Lastly, sonorous vibrations in water are transmitted but feebly to air; and those which are taking place in air are with difficulty communicated to water; but the communication is rendered much more easy by the interposition of a membrane between the air and the water.

327. The *Auditory* nerve, or nerve of Hearing, is adapted to receive and transmit to the brain the sonorous undulations produced in the surrounding medium by vibrating bodies. Now, it is obvious that it may be affected by these in various ways, especially in animals that inhabit the water. The vibrations excited in the liquid will be transmitted to the solid parts of the head, and thence to the nerve contained in it, without much interruption; and this, independently of any special apparatus of hearing. Indeed, the simplest form of this apparatus is only designed to give increased effect to the vibrations thus excited in the solid parts of the head; for it consists merely of a cavity excavated in their thickness, filled with fluid, and lined by a membrane on which the nerve of hearing is minutely distributed. This is the form of the organ of hearing in those of the Mollusca which possess any such organ.

328. Of the degree in which sonorous vibrations may be communicated to our own auditory nerves through the solid parts of the skull, we may easily satisfy ourselves, by closing the ears carefully, and placing any part of the head against a solid body which communicates with the one in vibration. In this manner we may hear the sounds produced by the latter, with considerable distinctness, though accompanied by an unpleasant jarring. A deaf gentleman was once agreeably surprised to find that when smoking his pipe, with the bowl resting on his daughter's piano-forte, he could distinctly hear the music she was producing from it; and many deaf persons may be made to hear conversation, by holding a piece of stick between their own teeth, and placing it against the teeth of the person speaking.

329. In animals which have the organ of hearing constructed upon the simple plan just mentioned, the force of the vibrations of the fluid contained in the cavity is increased by several minute stony concretions suspended in it, which act according to the second principle stated in § 326. They are termed *otolithes* or ear-stones; and some traces of them may be found even in Man and the higher animals. They may be found in the head of a boiled fish, where they are hard and brittle as porcelain, and they frequently attract attention at table, from their curiously smooth and polished appearance.

330. It appears, then, that a cavity excavated in the solid walls of the head, covered in externally by a membrane, having the auditory nerve distributed upon its walls, and filled with fluid, is the simplest form of the organ of hearing, and may be regarded as including all that is *essential* to the exercise of this function. On the other hand, in Man and the higher Vertebrata, we find a very complex structure, adapted to render the faculty much more perfect; by receiving impressions which make us aware, not only of the presence of a sounding body, but of its nature and direction, and of the pitch and peculiar quality of the sound; and also, it is probable, by taking cognizance of sounds much fainter than those which would be perceptible to the lower animals. Yet, even in the most complicated forms of the organ of hearing, we shall find that the *essential* part is still the same with that which forms the whole organ in the lower tribes; and that the faculty is still possessed, though in an inferior degree, when by disease or injury the *accessory* parts are prevented from acting.

331. The organ of Hearing, in Man, may be divided into three parts, the *external, middle,* and *internal* ear The former is the fibrocartilaginous appendage placed on the outside of the head, to receive and collect the sounds which are to be transmitted to the interior. The two latter divisions are excavated in a bone of remarkable solidity, the petrous (stony) portion of the temporal-bone. The use of the different hollows and elevations on the surface of the external ear of man is, probably, to direct the sonorous undulations towards the entrance of the canal which leads to the middle ear. The form of the external ear, in Quadrupeds, evidently adapts it to this purpose; and there are several which, like the Horse, have the power of changing its direction, by muscular action, in such a manner as to enable it to catch most advantageously the faintest sounds from any quarter. This is especially the case with timorous animals, such as the Hare or the Deer, which also have very large external ears.

332. The canal, *d*, plate 8, fig. 7, into which the external ear collects the sonorous vibrations, passes inward, until it is terminated by a membrane stretched across it, which is called the *membrana tympani*, or membrane of the *drum* of the ear, *g*. This forms the outside wall of a cavity excavated in the petrous portion of the temporal-bone, the inner wall of which is bony, and forms the partition between the middle and internal ear. The cavity of the tympanum, constituting the *middle* ear, is not one of the *essential* parts of the organ; for nothing analogous to it exists in fishes, nor in the lower reptiles. It contains air, and communicates with the back of the nasal cavity by a canal termed the *Eustachian* tube, *k*. It is the partial or complete closure of this tube, by swelling of its lining, or by the viscid secretion from it, that occasions the slight deafness common among those who are suffering from colds.

333. Within the cavity of the tympanum there is a very curious apparatus of small bones and muscles, which seems to establish a connexion between the membrane of the drum and the small membrane covering the entrance to the internal ear. These bones are four in number, and are termed the *malleus* or hammer, *a*, fig. 51; the *incus* or anvil, *b*; the *os orbiculare*, a minute globular bone, *c*; and the *stapes* or stirrup-bone, *d*. These bones are connected together in the manner represented in fig. 52, where *b* represents the membrana tympani; *c*, one of the long processes of the malleus, which is attached to the membrane; *d*, the head of the malleus, which articulates with the

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§ 324. How are sounds produced?—Describe the effect produced upon the air by the vibrations of sounding bodies. 325. Is air the only conducting medium?—How is it shown that water and wood conduct sounds?—How is it proved that a medium of some kind is necessary for this purpose? 326. What important fact is stated in regard to the action of the organ of hearing?—What four conclusions are drawn from experiments on this subject? 327. What is the use of the auditory nerve?—How do animals hear, which inhabit the water?—What is the simplest form of the organ of hearing? 328. How is it shown that sounds may be communicated through the solid parts of the skull?—Repeat the instance of the deaf gentleman, &c.

329. How is the acuteness of the simple organ of hearing increased?—On what principle?—What is said of the otolithes or ear-stones? 330. What, then, appears to be the simplest form of the organ of hearing?—In what respects is the ear of Man superior to this? —What is said of the *essential* part of the organ of hearing? 331. Describe the divisions of the organ of hearing in Man.—What is said of the uses of the external ear? 332 Explain the construction, and point out in the plate the parts, of the middle ear.—What is the occasion of deafness in a person who has a cold? 333. Describe the bones of the ear and their relative position, &c., in fig. 52.

incus; *e*, the other long process of the malleus, which is acted on by the minute muscle, *f*; *g*, the incus, of which one leg is in contact with the wall of the cavity, while the other is connected with the orbicular-bone, *h*; *i*, the stapes, the upper end of which joins the orbicular-bone, and the lower, which is of an oval form, is attached to the membrane that covers the entrance to the internal ear; and *k* is a small muscle which acts upon the stapes in such a manner as to regulate its movements.

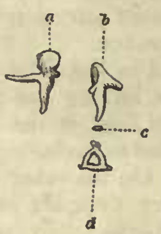

Fig. 51.—BONES OF THE EAR.

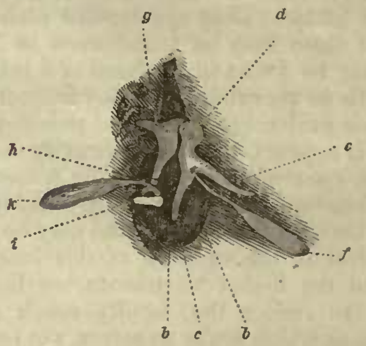

Fig. 52.—CAVITY OF THE TYMPANUM, WITH THE BONES IN THEIR PLACES.

334. The use of this apparatus is evidently to receive the sonorous vibrations from the air, and to transmit them to the membrane forming the entrance to the internal or essential part of the organ of hearing, in such a manner that the sonorous vibrations excited in the latter may be much more powerful than they would be if the air acted immediately upon it. The usual state of the membrane of the tympanum appears to be rather lax or slack, and, when in this condition, it vibrates in accordance with grave or deep tones. By the action of a small muscle lodged within the Eustachian tube, it may be tightened so as to vibrate in accordance with sharper or higher tones; but it will then be less able to receive the impressions of deeper sounds.

335. This state may be artificially produced, by holding the breath and forcing air into the Eustachian tubes, so as to make the membrane bulge out by pressure from within; or, by exhausting the cavity, by an effort at inspiration with the mouth and nostrils closed, which will cause the membrane to be pressed inwards by the external air. In either case, the hearing is immediately found to be indistinct; but it will be observed, that the experimenter thus renders himself deaf to grave sounds; while acute sounds are heard even more distinctly than before. If the sound be so acute that the membrana tympani will not vibrate in unison with it, the individual will not hear it, although it may be loud. It has been observed that some persons cannot hear the very shrill tones produced by particular insects, or even by birds, which are distinctly audible to others.

336. The internal ear is composed of various cavities that communicate with each other. Of these, the *vestibule* (*l*, plate 8, fig. 7) may be regarded as the centre; from it pass off, on one side, the *three semi-circular canals, m*; and on the other, the *cochlea, n*. The vestibule is the part which corresponds with the simple cavity that constitutes the whole organ of hearing in the lower animals, and the canals and cochlea may be regarded as extensions of it for particular purposes. It communicates with the tympanum, by a small orifice in the bony wall that separates them, called the *fenestra ovalis,* or oval window. This orifice is closed by a membrane, to which the lower end of the stapes is attached. The three *semi-circular canals* are passages excavated in the solid bone, and lined by a continuation of the same membrane that lines the vestibule; each passes off from the vestibule and returns to it again.

337. The *cochlea, n,* or snail-shell, also is a cavity excavated in the hard bone, and lined by a continuation of the same membrane; its form is almost precisely that of the interior of a snail-shell (whence its name), being a spiral canal, which makes about two turns and a half around a central pillar. This canal is divided into two, however, by a partition running along its whole length; which partition is partly formed by a very thin lamina of bone, and partly, in the living state, by a delicate membrane. The two passages do not communicate with each other, except at the top or centre; at their lower end, corresponding to the *mouth* of the snail-shell, they terminate differently; for while one freely opens into the vestibule, the other communicates with the cavity of the tympanum by an aperture termed the *fenestra rotunda,* or round window, which is closed by a membrane. Thus the internal ear communicates with the cavity of the tympanum by two minute orifices only—the *fenestra ovalis*, and the *fenestra rotunda* —both of them closed by membranes, against the former of which the *stapes* abuts, while the latter is free. A magnified view of a section of the semi-circular canals, and the cochlea, is given in plate 8, fig. 8.

338. The whole internal ear is lined by a delicate membrane, on which the auditory nerve is very minutely distributed; and terminates in *papillæ*, which are especially visible on the partition between the two passages of the cochlea. The cavities are completely filled with fluid, which is set in vibration by the movements of the stapes, communicated through the membrane of the *fenestra ovalis;* and these vibrations are probably rendered more free by the existence of the second aperture, the *fenestra rotunda.* It is by the influence of these undulations upon the expanded fibrils of the auditory nerve, that the sensation of sound is produced; but in what way the different parts of the *labyrinth*, as this complex series of cavities is not inaptly called, contributes to the performance of this function, is not yet known. In all but the lowest Fishes, these semi-circular canals exist; but there is no vestige of a cochlea. In the true Reptiles, a rudiment of the cochlea may be generally discovered. In Birds, this cavity is more completely formed, though the passage is not spiral, but is nearly straight; it is divided, however, like the cochlea of Man, by a membranous partition on which the nerve is spread out.

339. In almost every instance in which the semi-circular canals exist, they are three in number, and lie in three different directions, corresponding to those of the bottom and two adjoining sides of a cube; hence it has been supposed, and with much probability, that they assist in producing the idea of the *direction* of sounds. It has also been supposed that the *cochlea* is the organ by which we judge of the *pitch* of sounds; and this would seem to be not improbable, especially when we compare the development of the cochlea, in different animals, with the variety in the pitch of the sounds which it is important that they should hear distinctly, especially the voices of their own kind. The *compass* of the voice—that is, the distance between its highest and lowest tones—is much greater in Mammalia than in Birds, as is also the length of the cochlea. In Reptiles, which have little true vocal power, the cochlea is reduced to its lowest form, and in Fishes it disappears altogether.

340. That the *vestibule*, and the passages proceeding from it, constitute, even in man, the essential part of the organ of hearing, is evident from the fact, that when, as not unfrequently happens, the membrana tympani has been destroyed by disease, and the chain of bones has been lost, the faculty is not by any means lost, though it is deadened. In this state, the vibrations of the air must act at once upon the membrane of the fenestra ovalis, as in the lower animals which possess no external or middle ear, instead of striking the membrane of the tympanum, and being transmitted along the chain of bones.

341. It has been stated (§ 324) that the sensation of hearing is produced by the successive undulations or vibrations communicated to the ear, from the sounding body, by the air, or by a liquid or solid medium. This is the case with all *continued* sounds or *tones;* but single *momentary* sounds—such as those produced by the discharge of a pistol, the blow of a hammer, or the ticking of a watch—make their impression on the ear by a single shock. All continuous tones are, in fact, caused by a succession of such shocks, communicated to the ear with sufficient rapidity for the interval between them not to be distinguished. Thus, if a tight string be caused to vibrate, by pulling or striking it, there is occasioned, not one vibration only, but a long succession, every one of which gives a new impulse to the air, and produces a new impression on the organ of hearing.

342. These vibrations we can *see*, when they are sufficiently extensive, and we can always *feel* them, by placing a finger on the string. In the same manner, the vibrations of a bell, or a tuning-fork, continue long after the first blow; and these, though we cannot see them, may

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§ 334. What is the use of this apparatus?—What is said of the action of the membrane of the tympanum? 335. How may this membrane be tightened artificially, and what is the consequence of doing so?—Why are some persons deaf to certain sounds? 336, 337. Describe the parts of the internal ear.—Refer to plate 8, fig. 7, in connexion with the description.

§ 338. Describe the membrane of the internal ear.—What is said of the fluid contained in the cavities, and of its undulations?—What of the modifications of this part in fishes, reptiles, and birds? 339. What is said of the semi-circular canals, and of their use?—What of the use of the cochlea? 340. How is it shown that the vestibule is the *essential* part of the organ of hearing? 341. What is said of the production of continuous and momentary sounds?—How is this illustrated by the vibration of a string? 342. What is said of seeing and feeling vibrations?—How are continuous tones otherwise produced?—Upon what does the *pitch* of these sounds depend?

be readily felt by the finger. It is, in fact, in their power of continuing to vibrate after they have been struck, that the peculiarity of these resonant bodies consists. In other instances in which continuous tones are produced, the vibrations are kept up by the continued application of the original cause, and cease as soon as it is withdrawn; this is the case, for instance, in the string of the violin, when set in motion by the bow, and in the flute and organ-pipe, when caused to sound by the passage of air through them. In all these cases, then, the continued tones are due to a succession of impulses given by the sounding body to the air; and, according to the *rapidity* with which the impulses succeed each other, will be the *pitch* of the sound.

343. The *strength* or *loudness* of musical tones depends upon the force and extent of the vibrations communicated by the sounding body to the air. Thus, when the middle of a tight string is drawn far out of the straight line, and then let go, a loud sound is produced, and we can *see* that the space through which the string passes from side to side is considerable. As the extent of the vibrations of the string diminishes, the sound becomes less powerful; and when we can no longer see the vibrations, but only *feel* them, the sound is faint. The length of the undulations in the air corresponds with that of the vibrations in the sounding body, and consequently they will strike upon the tympanum with more or less force, as these are longer or shorter. The cause of the differences in the *quality* of musical tones—such differences, for instance, as are perceived between the tones of a flute, a violin, and a trumpet—is unknown; but they probably depend upon the different *form* of the vibrations.

344. The faculty of hearing, like that of sight, may be very much increased in acuteness, by cultivation; but this increase depends rather upon the habit of attention to the faintest impressions made upon the organ, than upon any change in the organ itself. Thus, the watchful Indian recognizes footsteps, and can even distinguish the tread of a friend from that of a foe; while his white companion, who lives among the busy hum of cities, is unconscious of such slight sound. Yet the latter may be a musician, capable of distinguishing the tones of all the different instruments in a large orchestra, of following any one of them through the part which it performs, and of detecting the least discord in the blended effects of the whole—effects which would be to his colored friend only a confused mass of sound. In the same manner, a person who has lived much in the country is able to distinguish the note of every species of bird which lends its voice to the general concert of Nature; while the inhabitant of a town hears only an assemblage of shrill sounds, which may impart to him a disagreeable rather than a pleasurable sensation.

345. Of the *direction* and *distance* of sounds, our ideas are for the most part formed by habit. Of the former we probably judge, in great degree, by the relative intensity of the impressions received by the two ears; though we may form some notion of it by a single organ (§ 339). Of the distance, we judge by the intensity of the sound, comparing it with that which we know the same body to produce when nearer to us. The ear may be deceived in this respect as well as the eye; thus the effect of a full band, at a distance, may be given by the subdued tones of a concealed orchestra close to us; and the Ventriloquist produces his deceptions by imitating, as closely as possible, not the sounds themselves, but the manner in which they would strike one's ear.

SENSE OF SIGHT.

346. By the faculty of Sight we are made acquainted, in the first place, with the presence of *light;* and, by the medium of that agent, we take cognizance of the form of surrounding bodies, their color, size, and position. As to the nature of Light itself, there is a difference of opinion; some philosophers believing that it is propagated by rays consisting of actual particles emitted from the luminous body; while others consider it more probable that it is transmitted by means of vibrations or undulations, analogous to those by which sound is propagated. An exposition of these theories, and the arguments and facts upon which they are based, may be found in works on the science of Astronomy. In the present connexion, it is of little consequence which doctrine is true; since we have to do alone with the laws that regulate the *transmission* of the rays of light, or their passage through different substances, which laws are the same under both theories. Some knowledge of these laws is requisite to a proper understanding of the beautiful action of the eye, and a short account of them will be here given.

347. The rays of light uniformly travel in straight lines, as long as they traverse the same medium (air, water, glass, or any other transparent body) without obstruction. In passing from a single luminous point into space, they diverge, or separate, in such a manner as to cover a larger and larger surface as they advance; while, at the same time, the intensity of the light is diminished. But when a ray passes from one medium into another of a different density, as from air into water, or from water into air, it is bent out of its straight course, or *refracted;* except when it happens to pass in a direction perpendicular to the plane which separates the two transparent bodies.

348. This may be proved by the following simple experiment: Place a piece of money (*a*, fig. 53) at the bottom of a cup or basin, and stand in such a position that the side of the vessel will just hide the coin from the eye. Then let another person fill the basin with water, the eye of the observer being kept in the same position as before. As the water is poured in, the coin will become visible, appearing to rise with the water. The effect of the water is to bend the ray of light coming from the coin, so as to make it meet the eye below the point which the ray would have reached, if it had proceeded in a straight line. Thus the eye of the observer, situated at the end of the line *a c*, could not see the coin in a straight line, because rays passing in that line would be interrupted by the side of the basin; but it receives the ray which was passing in the direction *a d*, and which was bent downwards at the moment of quitting the water.

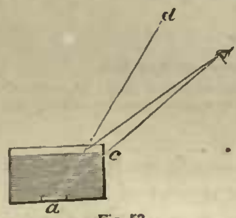

Fig. 53.

If, however, the eye had been placed directly over the coin, so that the ray, passing from the latter to it, would have emerged in a direction perpendicular to the surface of the water, no change in the apparent place of the object would have been made by pouring in the water, since a ray which passes from one medium to another, in a direction perpendicular to the surface which separates them, is not refracted. Those rays which pass out most nearly in this direction are refracted least, while those which pass out most nearly in the horizontal direction, are refracted most.

349. The general law of refraction, then, is, that rays passing from a denser to a rarer medium are refracted *from* the perpendicular; the degree of refraction being less in proportion as they are near the perpendicular. On the other hand, when rays pass from a rarer into a denser medium, they are bent *towards* the perpendicular; and this in a greater or less degree, according as their direction is more distant from, or nearer to, the perpendicular.

350. When the surface which separates the two media is not flat, but is convex or concave, a very important alteration is produced in the direction of the rays that fall upon it. Thus, let us suppose that three diverging rays, issuing from a point, *a*, fig. 54, traverse the air and strike upon a *convex* surface of glass, *b*, *b*. The central ray, *a c*, falls in a direction perpendicular to the surface of the glass at that point, and passes on unchanged in its course. But the ray, *a d*, falls upon the surface very obliquely; and consequently, in entering the glass, it will be bent towards the line *e*, which is perpendicular to the surface, and will pass onwards in the direction *f*. In the same manner, the ray, *a g*, will be refracted in the direction *i*. Hence these rays, now *converging*, would meet each other again, if sufficiently prolonged; and the point at which they meet is called the *focus*. To this point all the other rays which strike the convex surface, at a moderate distance from the central ray, will be also conducted.

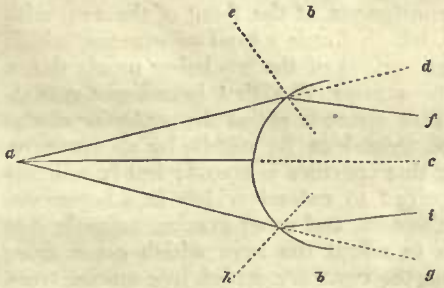

Fig. 54.

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§ 343. Upon what does the strength and loudness of a tone depend?—How is this shown by the vibration of a string?—What is said of the *quality* of musical tones? 344. What is said of the cultivation of the faculty of hearing?—How is this illustrated? 345. What is said of our ideas of the direction and distance of sounds?—What of the deception of the ear in this respect? 346. What is the office of the faculty of sight?—What is said of the nature of light?—For what physiological purpose is a knowledge of the laws of light requisite?

§ 347. When do rays of light pass in straight lines?—What is understood by the refraction of light? 348. Explain fig. 53, and show why the coin seems to be raised up by pouring in water.—If the eye had been placed directly over the coin, would the place of the latter have appeared to be changed?—Why not?—What rays are refracted least, and what most? 349. What, then, is the general law of refraction? 350. Explain fig. 54, and the operation of a convex lens upon rays of light.—What is the focus of a lens?

351. On the other hand, if the surface of the glass on which the ray falls be *concave* instead of *convex*, the diverging rays which fall upon it will be made to diverge still more. In both cases, it is easy to understand that the change of direction of the rays will be greater, as the curvature of the lens is more considerable. Thus, a convex lens has a longer or shorter focus (that is, it brings the rays to a focus at a greater or less distance from itself), according as the curvature of its surface is greater or less. The rays issuing from every point in an object, and falling upon a convex lens, are brought to a point or focus on the other side of the lens; and thus a distinct image or picture is formed upon any screen placed at the proper distance to receive it, every point in that image being the representative of the corresponding point in the object. But this image, according to the laws of optics, will be inverted.

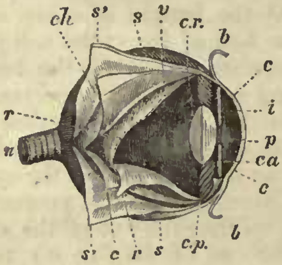

Fig. 55.—INTERIOR OF THE EYE.

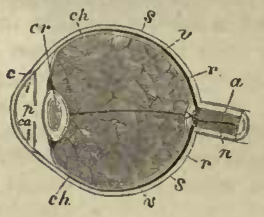

Fig. 56.—SECTION OF THE EYE.

c, cornea; *s*, sclerotic; *s'*, portion of the sclerotic turned back to show the subjacent parts; *ch*, choroid; *r*, retina; *n*, optic nerve; *ca*, anterior chamber; *i*, iris; *p*, pupil; *cr*, crystalline lens; *cp*, ciliary processes; *v*, vitreous humor; *b*, *b*, conjunctiva.

352. Now, the Eye, in its most perfect form—such as it possesses in Man and the higher animals—is an optical instrument of wonderful completeness, designed to form an exact picture of surrounding objects upon the expanded surface of the optic nerve, by which the impression is conveyed to the brain. The form of the eye is nearly globular. The walls of the sphere are composed of three *coats;* while in its interior are found three *humors* of a more or less fluid character. The outer coat, named the *sclerotic* (*s*, figs. 55, 56) is tough and fibrous, and is destined to support and protect the delicate parts which it contains. It covers the whole globe of the eye, except a part of the anterior portion, where it gives place to the transparent *cornea, c.* The cornea is set into a circular groove in the anterior margin of the sclerotica, in the same manner as a watch-glass is inserted into the case. The cornea is more convex than the rest of the globe, and projects forward beyond the circumference of the sclerotica. Beneath the sclerotica lies the second coat, called the *choroid, ch*, which is a delicate structure, consisting of blood-vessels and nerves. It has a deep black color, owing to its being covered with a layer of *pigmentum nigrum*, or *black pigment.*

353. The cornea becomes continuous, at the front of the eye, with the *iris* or colored portion, *i*, which forms a kind of curtain, which hangs behind the cornea. The surface of the iris being nearly flat, a space is left between it and the cornea, like that between the dial-plate and glass of a watch. This space is called the *anterior chamber* of the eye. The iris is perforated in its middle by an aperture, termed the *pupil, p.* In Man, this aperture is round; but in animals whose range of vision is required to extend widely in a horizontal direction, such as the sheep, the cow, and other grazing animals, it is lengthened horizontally, so as to admit the rays which come from either side. In the cat-tribe, on the contrary, which live among trees and high places, and which have to watch their prey in situations either above or below them, the pupil is elongated vertically.

354. By the relaxation and contraction of certain fibres in the iris, the size of the pupil is changed, according to the degree of light to which the eye is exposed. Thus the pupil contracts in a strong light, so as to exclude the rays which would be superfluous, and to prevent too many from falling upon the expansion of the optic nerve; while in a faint light it dilates, so as to admit as many rays as possible. If we notice the pupil of a man who is looking towards the mid-day sun, we shall see that it is contracted to a small round speck. Under the same circumstances, the pupil of a sheep would be contracted into a horizontal slit, and that of a cat into a vertical one.

355. The blackness of the pupil is owing to the pigment or black lining of the eye being seen through it. In many quadrupeds, the black pigment is replaced in a portion of the internal surface of the choroid, by a bluish layer of bright metallic lustre, and from this the light is brilliantly reflected, when the eye is seen in certain directions. This flashing of the eye, as it is often called, is apparent in cats and dogs, in an obscure light. The back of the iris is always covered with black pigment, the use of which is, to absorb the rays that would otherwise be reflected from one side of the interior of the eye to another, rendering the image indistinct.

356. Beneath the choroid-coat is situated the third layer, *r*, of which the wall of the eye is composed. This is a delicate film, chiefly consisting of nervous fibres which spread out from the optic nerve, *n*, and it is called the *retina.* It extends nearly as far as the iris, but is deficient in front of the eye.

357. The cavity of the globe is occupied by three *humors*, of different consistence, called the *aqueous, vitreous*, and *crystalline.* The aqueous humor is nearly pure water, being nothing else than the serum of the blood much diluted. It occupies the anterior chamber, *c a*, and a small space behind the iris, in front of the crystalline lens. The *vitreous* humor, *v*, resembles thin jelly in consistence, and occupies the greater part of the globe behind the iris. The *crystalline, cr*, is of much firmer consistence, resembling very thick jelly or soft gristle. It has the form of a double convex lens, the posterior surface of which is more convex than the anterior, and hence it is usually known as the *crystalline lens.* It is suspended in its place by a set of little bands proceeding from the choroid coat, and called the *ciliary processes, c p.*

358. The cornea is covered externally by a membrane termed the *conjunctiva, b, b.* This membrane is perfectly transparent where it covers the cornea, of which it seems like the outer layer. The front of the sclerotic is also covered by it, and it is there semi-opaque, and of a whitish color. The conjunctiva, however, does not pass back over the globe of the eye; but bends forward again, as seen at *b b*, so as to form the lining of the eyelids, at the edge of which it becomes continuous with the skin. Thus the smooth surfaces of the eye, and of the under-side of the lids, are both formed by this membrane, the mucous secretion from which serves to diminish the friction of one upon the other.

359. The smallest particle of any hard substance which may be interposed between these surfaces, produces great irritation. It cannot pass far backward, however, on account of the bend of the membrane at *b b;* and thus it may be always removed, if loose, with little difficulty. The lower lid can be drawn down so as to expose the membrane as far as this bend, and thus any loose particle upon its surface can be detected and removed; but the upper lid being longer, cannot be drawn out sufficiently for this purpose, and it is necessary to *evert* it, or turn it inside out. Much suffering may be avoided by a knowledge of the mode of performing this simple operation. Nothing more is requisite than to close the upper lid, without force; next to press upon its upper part with a pencil, bodkin, knitting-needle, or other hard body of small diameter, and then, taking hold of the eyelashes, to draw the lower edge of the lid forward and upward. By a dexterous movement of this kind, the lid can be everted without pain, and any offending particle can be readily removed from the lining membrane.

360. The globe of the eye is moved by six muscles, which are lodged within the bony cavity or *orbit*, hollowed out in the skull. All these muscles, except one, originate at the back of the orbit, and are inserted into the sclerotic-coat, near its front. Four of them are termed *recti*, or straight muscles. One of them, the *superior rectus, d* (plate 9, figs. 1 and 2), is inserted at the upper part of the eye, and, by its contraction, rolls the globe upward. Another, the *inferior rectus, e*, produces a corresponding movement downward. A third,

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§ 351. What is the effect of a concave glass upon the rays of light?—How is the change of direction of the rays proportioned?—Upon what does the length of the focus of a convex lens depend?—How is an image formed by a convex lens? 352. What is said of the eye as an optical instrument?—How many coats has the eye?—How many humors?—Describe the sclerotic coat, and refer to figs. 55, 56.—How is the cornea inserted into the sclerotic?—Describe the choroid-coat. 353. Describe the iris—The anterior chamber—The pupil, and its modifications in different animals. 354. How is the size of the pupil varied, and what is the use of this variation in size?

§ 355. To what is the blackness of the pupil owing?—What is the reason of the glistening of a cat's eyes in the dark?—What is the use of the black pigment? 356. Describe the retina. 357. What are the humors of the eye?—Describe them separately. 358. What is the conjunctiva?—How is it formed, and what is the use of its secretion? 359. What is said of the effect of a hard substance between the surfaces of this membrane, and how may it be removed? 360. How many muscles move the eye?—What are their names, situations, and mode of action?—Particularly describe the superior oblique.—Refer to plate 9 and point out these muscles.

PLATE IX.

ORGAN OF VISION.—THE EYE.

FIGURE 1.—THE RIGHT EYE, WITH ITS MUSCLES.

Displayed in the cavity of the orbit, on the vertical plane of a section corresponding to the middle of the arch of the eyebrow:—that is, as if the right side of the head were removed, as far as the middle of the right eyebrow, leaving the eye in its place, to be seen from the right.

FIGURE 2.—BOTH EYES, WITH THEIR MUSCLES,

As they appear upon a horizontal section through the orbits, immediately above the eyes.—As if the upper part of the head were removed, as far down as the top of the eyes, the observer looking at them from above. They are represented in this position, in order to show clearly the situation and action of the superior oblique muscle, and also the crossing or decussation of the optic nerve. The letters of reference indicate the same parts in both figures.

a, The optic nerve. *s*, figure 2, The chiasma or commissure of the optic nerve, whence each nerve extends forward and outward, passes into the eye at *t*, and becomes continuous with the retina. *b*, The common oculo-motory nerve, which is distributed to five of the muscles of the eye. *k*, Trunk of the fifth pair, a branch of which constitutes the ophthalmic nerve, and gives sensibility to the different parts of the eye.—The distribution of this nerve is seen in the left eye in figure 2. *l*, Artery of the eye. *c*, The elevator muscle of the upper eyelid. *d*, The superior rectus, or elevator of the eye. *e*, The inferior rectus, or depressor of the eye. *f*, The internal rectus. *g*, The external rectus. *h*, figure 2, The superior oblique muscle. *m*, Its pulley. *i*, figure 1, The inferior oblique muscle. In figure 2, parts of several of these muscles are removed, in order to display the others distinctly.

FIGURE 3.—THE LACHRYMAL APPARATUS.

a, The lachrymal gland. *b*, *b*, The lachrymal ducts, which collect the tears, and transmit them to the lachrymal sac, *c*, whence they pass into the cavity of the nose.

FIGURE 4.—THE LEFT EYEBALL,

SHOWING THE POSTERIOR SURFACE OF THE RETINA.

a, A small transparent spot, situated near the optic nerve, called the foramen of Soemmering, surrounded by a yellow halo, the *limbus luteus*. *b*, The optic nerve, cut off at its entrance into the retina. *c*, The central artery of the retina. *d*, *d*, Ramifications of the artery on the inner wall of the retina, seen through the two outer layers.

FIGURE 5.—THE FIBRES OF THE IRIS, DETACHED.

a, The pupil. *b*, The circular fibres at the central margin of the iris, by the action of which the pupil is diminished or enlarged. *c*, *c*, The radiating fibres, which proceed from the external border of the circular fibres.

FIGURE 6.—A PORTION OF THE PIGMENT MEMBRANE OF THE CHOROID COAT

HIGHLY MAGNIFIED.

It is seen to consist of regular six-sided plates, the tissue of which is filled with grains of coloring matter.

FIGURE 7.—THE GLOBE OF THE EYE,

MAGNIFIED, AND SEEN IN FRONT.

This figure represents the second or choroid coat, the sclerotica being removed. *a*, The pupil. *b*, The iris. *c*, *c*, The choroid membrane. *d*, *d*, The ciliary nerves running from every part of the circumference towards the iris. *e*, *c*, The ciliary arteries.

FIGURE 8.—THE GLOBE OF THE EYE,

SEEN IN THE SAME VIEW.

The iris is removed, in order to display the ciliary processes, and their position in regard to the lens. The ciliary nerves and arteries are the same as in fig. 7.

FIGURE 9.—THE ANTERIOR HALF OF THE GLOBE OF THE EYE,

SEEN FROM BEHIND.

The lens and the vitreous humor are removed. *a*, The pupil. *b*, *b*, The posterior surface of the iris, called, from its dark grape-like color, *uvea*. *c*, *c*, The ciliary processes. *d*, *d*, The internal surface of the choroid. *e*, *e*, The cut edges of the choroid and sclerotic.

FIGURE 10.—THE POSTERIOR HALF OF THE GLOBE OF THE EYE,

SHOWING ITS INTERNAL SURFACE.

a, *a*, The cut edges of the sclerotic, choroid, and retina. *b*, *b*, The internal surface of the retina. *c*, The foramen of Soemmering. *d*, The optic nerve. *e*, Branches of the central artery of the retina.

FIGURE 11.—*A*, Front View of the Crystalline Lens. *B*, Side View of the Lens.

a, Its anterior and least convexity. *b*, Its posterior and greatest convexity.

FIGURE 12.—THE CRYSTALLINE LENS,

AFTER BEING IMMERSED IN BOILING WATER.

The lines on the surface show its division into three parts.

FIGURE 13.—THE THREE SEGMENTS OF THE CRYSTALLINE LENS.

The faces of the segments show the concentric layers of which it is composed (like the coats of an onion). The nucleus, or central portion of the lens, is seen on one of the segments, and on the other two are corresponding depressions.

FIGURE 14.—COMPOUND EYES OF THE BEE,

HIGHLY MAGNIFIED, SHOWING THE DIVISION INTO FACETS, AND ALSO THE CONICAL SHAPE OF EACH SEPARATE PORTION.

A, Facets still more highly magnified. *B*, The same with hairs growing between them.

PRINCIPLES OF PHYSIOLOGY.

ORGAN OF VISION.
(THE EYE.)

Fig 1.

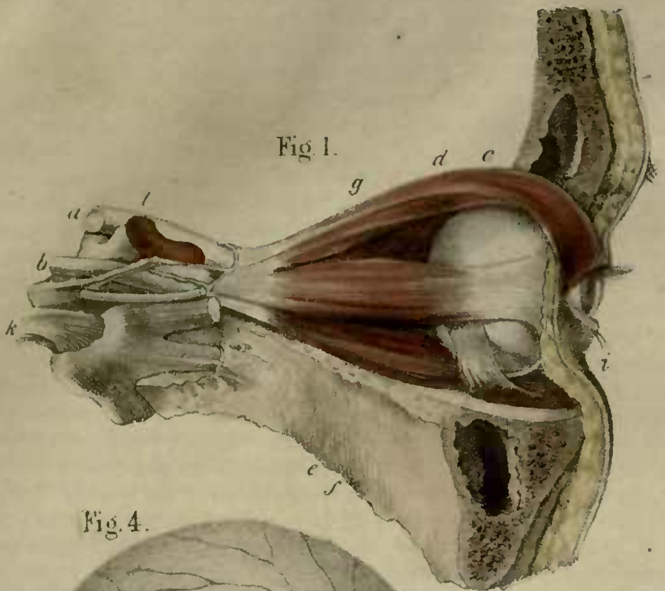
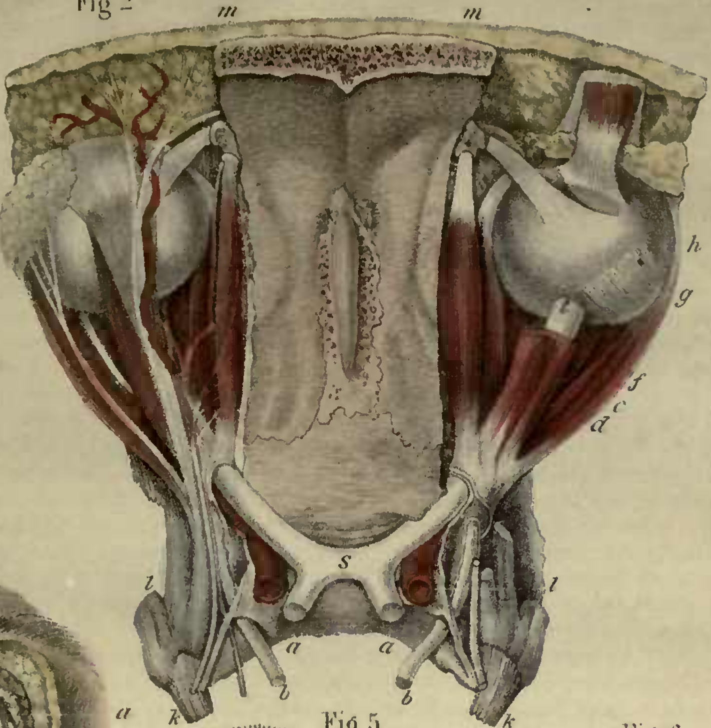


Fig 2



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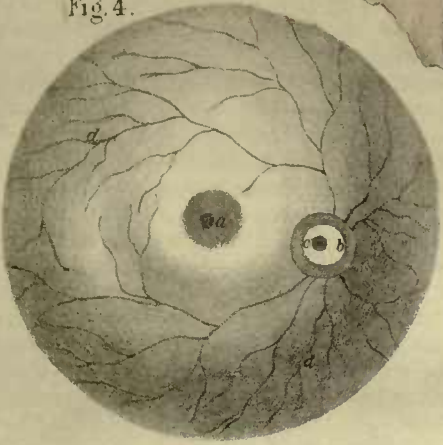

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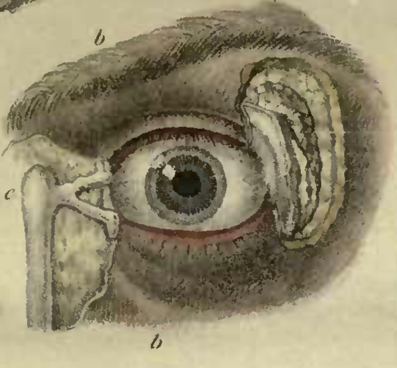

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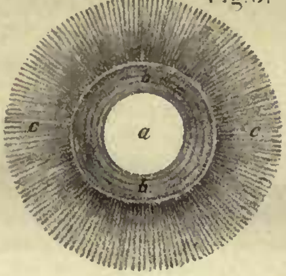

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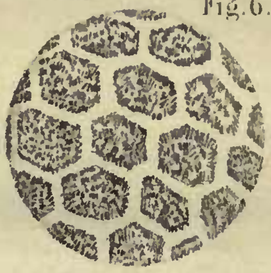

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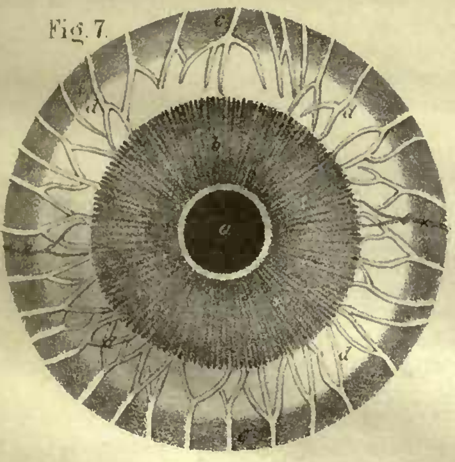

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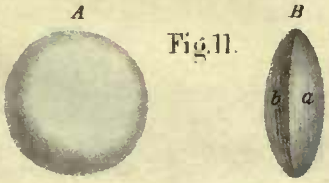

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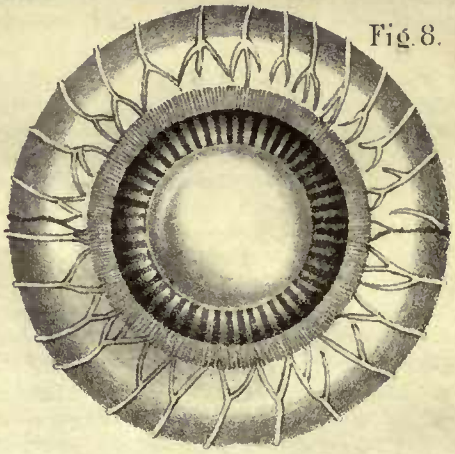

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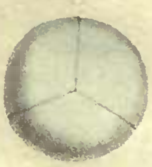

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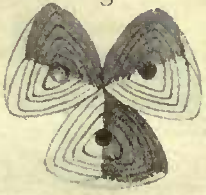


Fig 9.

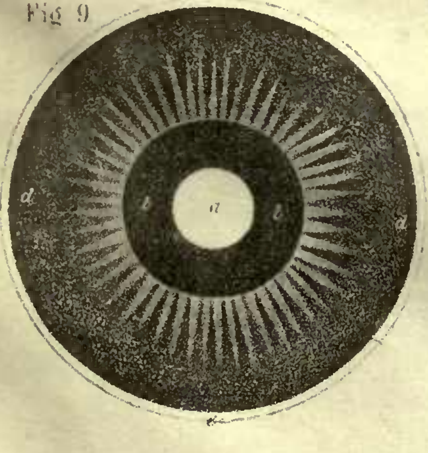


Fig. 14.

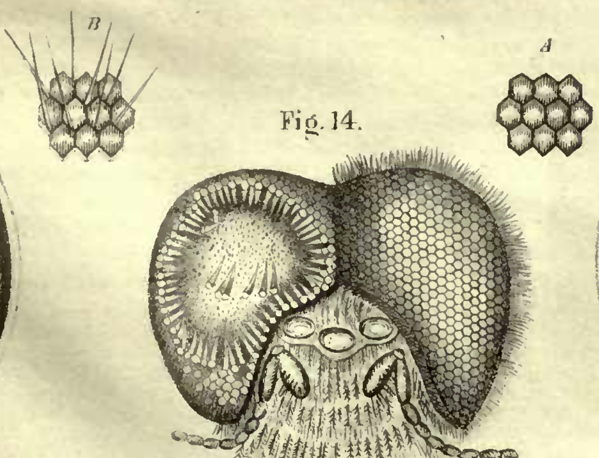
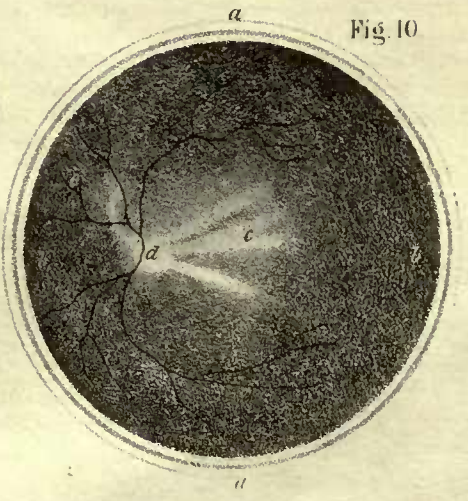


Fig. 10



Lith of Kellogg

Entered according to Act of Congress, in the year 1850, by Kellogg & Comstock, in the Clerk's Office of the District Court of Connecticut.

Hartford, Conn.

the *internal rectus*, *f*, rolls the globe inward, or towards the nose; while a fourth, the *external rectus*, *g*, turns it outward. Besides these, there is a remarkable muscle, the *superior oblique*, *h*, fig. 2, in connexion with which there is a very curious and beautiful contrivance. It originates at the back of the orbit, proceeds forward, and, when it reaches the front, its tendon passes through a little cartilaginous pulley, *m*, and then turns backward to be inserted into the sclerotic-coat, at a point considerably behind the pulley. The direction of its action is thus changed, just like that of a rope which is passed through a block in the rigging of a ship, and, by drawing downward upon which, a sail is raised. This muscle rolls the eye downward and inward. The *inferior oblique*, *i*, fig. 1, arises from the lower border of the orbit. It turns the eye upward and outward.

361. The eyebrows, eyelids, and eyelashes, serve in various ways for the protection of the eyes. In Birds and Reptiles, there is a *third* eyelid, which is drawn *across* the eye by a muscle that passes through a loop in it. This *nictitating membrane*, as it is called, is semi-transparent, and it seems to protect the eye from the too powerful rays of light, without preventing the power of vision. Beneath the upper eyelid, in the upper and outer portion of the orbit, is situated the *lachrymal gland*, *a*, plate 9, fig. 1. This gland is continually pouring out a watery secretion, the lachrymal fluid or tears, which moistens the globe of the eye, and keeps it free from impurities. This secretion is increased by mental emotion, or by irritation of the eye, If the edges of the lids be carefully examined, there will be seen upon each of them, close to the inner corner, a minute spot, which is the entrance to a small canal, called the *lachrymal duct*, *b*, *b*. The two ducts, one commencing at the corner of each lid, soon unite into a single canal, which swells out into a sort of reservoir, the *lachrymal sac*, *c*, that lies upon the side of the upper part of the nose, and from this a canal passes down into the cavity of the nose. By this apparatus, the fluid poured by the lachrymal glands over the eye is drawn off, after washing its surface, and carried into the nose, where it is got rid of by the current of air which passes through the nostrils in breathing. The lachrymal fluid, when the eyelids are closed, passes along the gutter formed by the meeting of their edges.

362. The structure of the eye, and the general actions of the parts connected with it, having thus been described, some of the phenomena of vision will be briefly noticed.

363. The rays of Light which diverge from the several points of any object, and fall upon the front of the cornea, are refracted by its convex surface, while passing through it into the eye, and are made to converge slightly. They are brought more closely together by the crystalline lens, which they reach, after passing through the pupil; and the refracting influence of the lens, together with that produced by the vitreous humor, is such as to cause the rays that issued from each point to meet in a focus on the retina. As every point is thus represented in its proper position relative to others (except that those which were above are now below, and *vice versa*), a complete inverted image or picture of the object is formed upon the retina. This is shown in fig. 57; where, for the sake of convenience, two rays only are represented as issuing from each of the two extremities of an object, *a*, *c*. These rays cross each other in the middle of the eye, those from *a* being brought to a focus at *b*, and those from *c* at *d*; and as all the other rays are refracted in the same manner, a complete inverted picture of the object is formed at the back of the eye.

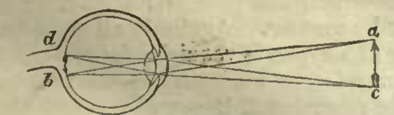


Fig. 57.

364. This fact may be seen, by taking the eye of a rabbit, cleansing it of the fat and muscles which adhere to its back part, and bringing a candle in front of it; when, by looking at the back, the transparency of the sclerotic-coat will allow the inverted image of the candle to be distinctly seen upon the retina. Or, if the eye of a sheep or an ox be taken (the coats of which are thicker than those of the rabbit, and will not allow the passage of light), a part of the sclerotic and choroid coats should be cut out at the back part, and the portion of the retina thus left bare should be covered with a piece of tissue paper, for the purpose of keeping in the vitreous humor. A similar image of all the objects in front will be seen through the tissue paper. In performing these experiments, the eye should be perfectly fresh, as the cornea and humors soon lose their transparency, and the picture becomes indistinct.

365. The black pigment, which is situated immediately behind the retina—that is, in contact with its external surface—is destined to absorb the rays of light as soon as they have passed through the retina, so as to prevent them from being reflected from one part of the eye to the other, which would cause great confusion and indistinctness in the picture. Hence it is that, in those individuals, both among man and the lower animals, in whose eyes this pigment is deficient, vision is extremely imperfect. Such individuals are termed Albinos, and their eyes present a very peculiar appearance. The color of the iris is a bright red, owing to the great number of minute blood-vessels. The choroid-coat, seen through the pupil, has exactly the same aspect; so that the pupil is not readily distinguished. During the day, the vision of these Albinos is very indistinct, and the glare of light is painful to them; and it is only when twilight comes on, that they can see clearly and without discomfort.

366. By the perfect construction of the eye, the defects to which ordinary optical instruments are liable, are avoided. A full explanation of the causes of these defects, and of the methods in which they are corrected by the structure of the eye, belongs to the science of optics. It may be mentioned, however, that one of these, called *spherical aberration*, results from the fact that those rays which fall upon the outer parts of an ordinary convex lens, meet in a focus nearer the lens than those which fall in the centre. In optical instruments, this is remedied by using only the central portion of the lens; thus cutting off a great portion of the light, and rendering the image dark. But, in the eye, the difficulty is completely avoided by the adjustment of the unequal curvatures of the cornea, and of the two surfaces of the crystalline lens, in such a manner that the rays are brought to the same focus. *Chromatic aberration*, or that defect which causes the edges of an object seen through a microscope to appear colored with different tints, is also corrected by the combination of the lenses of the eye, the different density of the humors of which is adapted exactly to the purpose. Indeed, the first idea of uniting glasses of different kinds, so as to produce what is called an *achromatic* lens, of the kind now employed in the best instruments, was taken from the eye. The eye also possesses the power of adjusting itself perfectly to the vision of objects situated at different distances—an arrangement which is imitated in optical instruments only in the most bungling manner. The mode in which this adjustment of the eye is effected is not yet explained.

267. It frequently happens, in advanced life especially, that the convexity of the cornea and the refracting power of the humors diminish; and, in such cases, the eye is no longer able to accommodate itself to near objects, the rays from which are not brought to a focus by the time they reach the retina, and the individual is said to be *long-sighted*. This defect may be remedied by the use of convex glasses. On the contrary, there are other cases, in which the cornea is too convex, and the rays from distant objects are brought to a focus before they reach the retina. This is the cause of *near-sightedness*, which is remedied by using double concave glasses.

368. In the choice of spectacles or eye-glasses, for these purposes, particular care should be taken that they are not so powerful as to produce a *strained* feeling in the eye. Convex glasses should never be used of such power as to magnify objects, nor concave glasses of such power as to diminish them; the proper degree of strength in both kinds of glasses being only that which will enable the eye to see with distinctness. The evil influence of using spectacles of too high power is not confined to the straining of the eyes. That feeling soon ceases; but it is because the eye adapts itself to the glasses, and thus undergoes a change which might otherwise have been deferred for years.

369. The facility with which distant or minute objects may be perceived, is much influenced by the degree of attention directed to them. Thus, a person sees a balloon, or a faint star, in a clear sky, as long as his attention is fixed upon it; but, if he withdraw his eye for a moment, he is unable to find the object again until it is pointed out to

§ 361. What is the use of the eyebrows, eyelashes, and eyelids?—Describe the third eyelid of Birds and Reptiles, and state its use?—Describe the situation and secretion of the lachrymal gland, and its uses.—How is the lachrymal fluid carried off?—Refer to plate 9, and point out the parts of the lachrymal apparatus. 363. Explain the manner in which an inverted image of an object is formed upon the retina. 364. How may the picture upon the retina of a rabbit or a sheep be observed?

§ 365. What is the use of the black pigment?—What is the cause of the imperfect vision of Albinos? 366. What defects, to which optical instruments are liable, are avoided by the construction of the eye?—Explain the mode in which spherical and chromatic aberration are corrected?—What is said of the adaptation of the eye to distances? 367. What is the cause of long-sightedness?—What of near-sightedness?—How may these defects be remedied? 368. What is said of the choice of spectacles? 369. What is said of the attention, as connected with sight?—What of the combination of touch with sight?—Describe the case of the boy whose sight was restored.

him. Sailors, from long habit of using their eyes in search of distant objects, are able to descry land, or a far-off sail, when, to the eye of the landsman, the horizon appears vacant. The sense of sight is much assisted by that of touch, and the combination of the two senses, by which the child learns to judge of the nature of objects, is the result of experience. This is shown by cases where a young person, having been blind from birth, is restored to sight. In one very interesting instance of this kind, a boy of twelve years of age, after his sight became tolerably correct, saw every thing *flat*, as on a picture, and it was some time before he was able, by sight alone, to judge of the real forms, characters, and distances of objects around him. He was well acquainted with a dog and a cat, by *feeling*, but he could not remember their respective characters when he *saw* them. Being thus puzzled, one day, he took up the cat, and felt her attentively; at the same time, looking steadfastly at her, and then setting her down again, he said, "So, puss, I shall know you another time."

370. The eyes of Insects are of an entirely different kind from that of Man. On each side of the head of a fly, or bee, is situated a brown projecting hemispherical body, the surface of which, under the microscope, is seen to be divided into an immense number of six-sided facets, which vary in number in different insects. In the eye of a butterfly, seventeen thousand have been counted; in that of a species of beetle, twenty-five thousand; in that of the common house-fly, four thousand. Each of these facets forms the front or cornea of a distinct eye, which is conical in its form, the apex of the cone being directed towards the expansion of the optic nerve within the hemispherical body. No two of these facets have the same direction; so that a separate eye, as it were, is provided for every point to be viewed, and thus the lack of power to move the eye is compensated. The compound eye of the bee is represented in plate 9, fig. 5.

371. There are many interesting topics connected with Vision, which the space allotted to that subject will not allow to be introduced here. Among these are, the science of Chromatics, or the Philosophy of Colors; the causes of *single vision*, or of our seeing only *one* object, while pictures of it are formed upon *both* retinæ; the reasons why we see objects in an *erect* position, while their images on the retina are *inverted*. The latter question, in particular, has given rise to great discussion. The student, who wishes to pursue the investigation of these and kindred subjects, should consult some of the numerous excellent treatises on the science of Optics.

CHAPTER XII.

MOTION.—STRUCTURE AND ACTION OF MUSCULAR TISSUE.

372. The different modifications of the faculty of Sensation, which have been described in the preceding chapter, enable Man and other animals to become acquainted with what is going on around them. But they possess another faculty, that of *spontaneous movement*, which serves the double purpose of enabling them to act upon the inanimate world around them, and of communicating to each other their feelings and ideas.

373. The movements of animals are effected by the action of a peculiar property, called *contractility*. This property consists in the power which certain parts of the body possess, of contracting suddenly when excited to do so, and of afterwards lengthening again by relaxation or slackening. In the higher animals, this property is nearly restricted to a peculiar tissue, called *muscular fibre*. In Vertebrated animals, the muscles, which are the active instruments of all their movements, form the greater part of the mass of the body, and constitute what is commonly known as the flesh or meat.

374. Every muscle is formed by the union of a number of bundles, which are united together by means of areolar tissue, and are themselves composed of bundles still more minute, united in a similar manner. These, again, may be separated in the same way; and at last we come to the *primitive fibres* of which this tissue is composed. Each of these primitive fibres consists of a delicate membranous tube, inclosing a great number of *fibrillæ*, or extremely minute fibrils, which are not capable of further division. The diameter of these fibrils is nearly the same in all animals, being about 1-10,000th of an inch.

375. Under the influence of certain exciting causes, or *stimuli*, muscular fibres suddenly and forcibly contract. Their two ends approach each other, and they swell out in the middle, to a corresponding degree. This causes a like change in the bundles which are made up of these fibres; and thus the whole muscle, when shortened by the drawing together of its two ends, is greatly enlarged in diameter, especially towards its middle. This may be readily observed by bending the fore-arm upon the arm, as when the hand is carried to the mouth, and feeling the fleshy mass in front of the arm, between the shoulder and the elbow. The actual bulk of the muscle is not changed by the act of contraction, for its enlargement in diameter is exactly equivalent to the shortening of the distance between its extremities.

376. The extremities of muscles are usually attached to bones, which their contraction causes to move one upon the other. One of these attachments is called the *origin*, and the other the *insertion* of the muscle. The origin is at that part which is the most fixed, and the insertion at that part which is moved by the contraction. Thus, the muscle just mentioned has its origin at the shoulder, which is fixed, or nearly so, and its insertion in the bones of the fore-arm, which is moved by it. Muscles are seldom *directly* attached to bones, but are usually united with them by means of *tendons* or *sinews*. These tendons are sometimes cylindrical, tapering from the muscle to the point of their insertion; and sometimes they are broad flat bands. Examples of the first kind are some of those which move the hand and fingers; they arise from the muscles which form the fleshy part of the fore arm, and may be felt at the wrist as hard, round cords.

377. Muscles are commonly divided into *voluntary* and *involuntary*, according as they act in obedience to the will, or are not under its dominion. There are, however, many muscles whose actions are usually of an involuntary character, but which are capable, to some extent, of being controlled by the will. Thus, the muscles concerned in breathing continue to act, even when the brain has been removed; and, in the most profound sleep, when the will can have no influence over them; but yet, these same muscles are made use of in speaking and singing, which are voluntary actions. On the other hand, many other muscles, the actions of which are usually voluntary, are sometimes made to act independently of, or even contrary to, the will. Such are those muscles which are excited by the emotions, and are called into play in laughing, crying, sobbing, &c. We often have the strongest desire to check these actions, on account of the unfitness of the time or place for their manifestation, and yet we are unable to do so.

378. The vigorous action of the muscular structure is dependent upon several causes. In the first place, it requires an active nutrition of the muscles themselves. Firm, plump, and high-colored muscles act with greater force than those which are pale and flabby, even though the size of the latter may be greater. Again, in all the most active animals, a constant supply of oxygen is requisite for muscular vigor. This is conveyed to the muscles, in Birds and Mammalia, by the blood (§ 56); in Insects, on the other hand, it actually enters the muscular tissue, in the state of atmospheric air (§ 91). The energy of muscular contraction also depends, in a great degree, upon the power of the stimulus which is transmitted to the muscles through the nervous system. This is frequently observed in instances of great nervous excitement; as when a person is under the influence of violent passion or insanity. A delicate female is thus often a match for three or four strong men, and can even break cords and bands that would hold the most powerful man, in his ordinary state.

379. The sense of fatigue, which comes on after prolonged muscular exertion, is really dependent upon a change in the brain, though usually referred by us to the muscles which have been exercised. This fatigue is felt after *voluntary* motions only, for the very same

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§ 370. Explain the structure of the compound eye of insects.—How is lack of motion in these eyes compensated? 372. What is the use of the faculty of Sensation?—What of that of spontaneous movement? 373. How are the movements of animals effected?—In what does the property of contractility consist?—To what tissue is this property restricted in the higher animals? 374. How are the muscles formed?—What is the diameter of the muscular fibrils?

§ 375. What is the effect of contraction upon the length and diameter of a muscle?—How may this change be observed? 376. Describe the attachments of muscles.—At what part is the origin, and at what part the insertion, of a muscle?—Where is the origin, and where the insertion, of the large muscle of the arm?—What are tendons?—What examples are given of tendons of the cylindrical form? 377. How are muscles divided?—What is said of involuntary muscles sometimes becoming voluntary, and *vice versa?* 378. Upon what causes does the vigorous action of muscles depend?—How are they supplied with oxygen?—What instances are given of great muscular power under nervous excitement? 379. On what does the sense of fatigue depend?—Why is fatigue felt only after voluntary motions?—Why do Birds and Insects perform long flights without fatigue?

muscles may be kept in *reflex* action (§235, &c.) for a much longer time, without any fatigue being experienced. Thus, we never feel tired of breathing; and yet a forced voluntary action of the muscles of respiration soon causes fatigue. The voluntary use of the muscles of our limbs, in walking or running, soon causes weariness; but similar muscles are used, in Birds and Insects, for very prolonged flights, without apparent fatigue; and, since the actions of flight may be performed after the brain has been removed (§243, 266, &c.), these actions may be considered as of a reflex character, and the absence of fatigue is thus accounted for.

380. The *energy* of muscular contraction appears to be greater in Insects, in proportion to their size, than in any other animals. Thus, a Flea will leap sixty times its own length, and move as many times its own weight. The same muscular energy in a man of six feet high, and weighing one hundred and seventy pounds, would enable him to leap to the distance of three hundred and sixty feet, or more than twenty rods, and to move a weight of over ten thousand pounds. A species of Beetles can support a weight equal to at least five hundred times that of its own body; and another, by the power of its jaws, has been known to gnaw a hole of an inch in diameter in the side of an iron canister in which it had been confined. The rapidity of the movements of Insects is also so great, that the vibrations of the wings, in some species, have been calculated at *several hundred*, and, in some of the smaller insects, at *many thousand*, in a second of time.

THE APPARATUS OF MOVEMENT IN GENERAL.

381. The organs by which are produced the *locomotion* (change of place) of animals, their attitudes, and other important actions of a mechanical nature, may be divided into *active* and *passive*. The *active* organs are those which have peculiar vital powers within themselves, and which exert these powers by giving motion to other parts. To this class, therefore, belong the muscles. The *passive* organs, on the other hand, are those which perform no action of themselves, which have no power but that of yielding a simply mechanical support, and which, consequently, perform no movements but such as they are made to do by the muscles. Of this kind are the hard parts which form the skeleton or solid frame-work of the body.

382. In the lower tribes of animals, the muscles are all inserted in the soft and flexible membrane which covers the body. By acting upon this membrane, they can change the form of the body in such a manner as to cause it to move, either altogether or in part. This is the case, for example, with the Earth-worm and the Leech, which are furnished with two sets of muscular fibres, one running along the body, and the other passing around it in rings. By the contraction of the former, the two ends are drawn together, so that the body is shortened; while, by that of the latter, its diameter is lessened, so that it is necessarily lengthened. By these two movements, which take place alternately, the progression of the animal is accomplished; and, by varying the contractions of one part or another, almost any form and direction can be given to this soft and flexible body.

383. But in the higher animals, the apparatus of movement consists, not only of muscles, but of a frame-work of solid pieces, which serves to augment the precision, force, and extent of the movements, while, at the same time, it determines the general form of the body, and protects the viscera against external forces. This solid framework or *skeleton* is sometimes internal, as in Man and the other vertebrated animals, and sometimes external; forming a shell, as in the lobster and other similar animals.

384. The *bones*, of which the skeleton of Man is composed, are the hardest parts of the body. They exist, at first, in the state of *cartilage* or *gristle*, which is gradually converted into bone by the deposition of phosphate and carbonate of lime. This process, which is called *ossification* (or bone-making), commences at certain places in the interior of the cartilage, called *points* or *centres of ossification*, and spreads from them to the outer surfaces.

385. In their perfect state, the mixture of earthy and animal matter in the bones renders them hard, without being brittle; and tough, without being pliable. The earthy matter gives them their strength and firmness, and the animal matter their vitality, growth, and nutrition. The animal matter may be separated by soaking a slender bone in a diluted acid, which dissolves the lime, and leaves the bone of the same size and shape as before, but so soft and flexible that, if a long bone, it may be tied in a knot. The earthy portion may also be obtained separately, by exposing the bone to the action of a hot fire, which completely burns out the animal matter, leaving the bone white and brittle, so that it may be easily broken, and even crumbled, into fragments.

386. The bones do not arrive at their perfect state until about the twentieth year. In the bones of children, it has been estimated that the earthy matter constitutes one-half; in adults, four-fifths; and in old persons, seven-eighths. The bones of young children are, therefore, yielding and flexible. This is a wise provision against the accidents to which children are liable. If they had perfect bones, every fall might break them; but, as it is, their bones bend to the shock, and again recover their shape, so that a child may fall from a considerable height, without permanent injury, while a similar accident would fracture the bones of an adult. In old age, on the contrary, the opposite is the case. The bones become unyielding and brittle, and are exceedingly liable to be fractured. A simple slip-down, which a man of thirty would scarcely feel, often breaks the leg of one of seventy. When, as is sometimes the case, the muscles of an old person retain a power and vigor disproportionate to the strength of their bones, the latter may even be fractured by a severe muscular exertion. Thus, there is a well-attested instance of an aged dandy, who broke his arm in attempting to pull on a tight glove.

387. The inside of the bones is generally porous or spongy, being composed of a great number of small cells. This arrangement increases their lightness, while it does not diminish their strength. In the long bones, as those of the thigh and arm, the two ends are usually spongy, while the middle portion, or shaft, is hollow, and contains marrow. The cylindrical shape of these bones, however, renders them as strong as if they were solid. This fact is owing to the mechanical principle on which they are constructed. The form of the arch is that which best resists pressure, and since the hollow cylindrical shape is formed by two arches set together, it follows that it is best adapted to sustain a heavy weight. This principle may be illustrated, by rolling up a sheet of paper in the form of a cylinder, holding it at both ends, and hanging over the middle a string with a weight attached. It will now be found capable of sustaining a considerable weight; but if the paper-roll be flattened, so as to destroy its cylindrical form, the same weight will at once break it down in the middle.

388. The different portions of the skeleton are *articulated*, or united by joints to each other, in such a manner that they can move with more or less freedom. These joints or articulations are of several kinds. Those bones of the skull which surround and protect the brain are very firmly united by what are termed *sutures* (or seams), which are formed by the interlocking of the jagged edges of one bone into corresponding notches of the adjoining one. So firmly are the bones united in this manner, in the adult, that it is difficult to separate them without breaking away some of the projecting parts. In the skull of the infant, however, the bones are only united by a membranous substance; and there is a point at the top of the head which is not covered by a bony layer until some months after birth. In other articulations, where little or no motion is required, the adjacent surfaces of the bones are united by an intervening layer of cartilage, and also by fibrous membranes which inclose the articulations. The vertebræ, or pieces of the back-bone, are joined in this manner.

389. The proper movable articulations, by which the limbs are connected with the trunk, and the different parts of the limbs to each other, are those usually called *joints*. In these, the surfaces of the adjacent bones are not united in any other way than by the ligaments

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§380. What is said of the energy of muscular contraction in insects?—What examples are given?—What if the muscular energy of a man were equal to that of a flea, in proportion to his size?—What is said of the rapidity of the movements of insects? 381. Into what two classes are the organs of locomotion divided?—How do the active differ from the passive organs? 382. Where are the muscles inserted in the lower animals?—Describe the mode in which the movements of the worm and leech are effected. 383. In the higher animals, of what does the apparatus of movement consist?—How does the skeleton of man differ from that of the lobster, in position? 384. In what state do the bones of man originally exist?—How is cartilage converted into bone?

§385. What are the respective uses of the earthy and animal portions of bones?—How may the two portions be separated from each other? 386. When do the bones arrive at their perfect state?—What is the proportion of earthy matter in the bones of children?—In adults?—In old persons?—What good purpose is served by the flexibility of the bones of children?—What is said of the liability of the bones of old persons to be fractured? 387. What is said of the structure of bones?—How is the strength of the cylindrical form of long bones illustrated? 388. What is said of the articulations?—How are the bones of the skull united?—What is said of the firmness of the sutures?—What of the infant's skull?—How are the vertebræ united? 389. What are usually called *joints?*—How are these joints formed?—What is synovia?

and muscles which surround them, and they have a free gliding movement over each other. They are covered by cartilage, which does not pass from one bone to the other, but forms a thin layer over the end of each, and presents a very smooth surface, which greatly facilitates the motion of the joint. These surfaces are kept moist by a fluid, termed *synovia*, secreted by a serous membrane, which forms a closed sac or capsule over them.

390. The beautiful smoothness of the surfaces of the joints, and the manner in which the bones are held together by the muscles and ligaments, is well seen by examining the knuckle-joint at the lower end of a leg of mutton (before being cooked), and the other joint which connects it with the bones at the top. These two joints are examples of the two principal varieties of freely-movable articulations—the *hinge-joint*, and the *ball-and-socket* joint. In the first of these, the surfaces of the bones are so formed that the movement, though free as regards its extent, is very limited in its direction, being restricted to a backward and forward action in the same line, just like that of a common hinge. In the second, the end of one bone is formed into a rounded head or ball; and this is received into a corresponding socket or cup in the other, the edge of which is usually deepened by cartilage. In this manner, the bone which carries the ball is enabled to move upon the other in any direction, unless checked in other ways.

391. Of the hinge-joint, we have examples in the elbow, the knee, and the joints of the fingers and toes. Of the perfect ball-and-socket joint, we have, in Man, only two examples—the shoulder, and the hip. In the former, the socket is much shallower than in the latter; and the motions of the arm are, consequently, more extensive than those of the thigh. The wrist and the ankle-joint are of an intermediate character; the former more resembling the ball-and-socket, and the latter the hinge-joint.

392. All these joints are more or less subject to *dislocation*, by violence of different kinds. This takes place by the slipping away from each other of the two surfaces, which ought to be in contact. Thus the head of the humerus or arm-bone may slip over the edge of its socket, so as to lie entirely on the outside of it; and this, in consequence of the shallowness of the cup, happens not unfrequently. The head of the thigh-bone, also, may slip out of its socket; but this accident is more rare, on account of the deepness of its cup. The elbow and knee-joints, as also those of the wrists, ankles, fingers, and toes, may be dislocated by the slipping of one surface on the other, either forward, backward, to one side, or to the other. One of the most common dislocations is that of the thumb, the lowest articulation of which has rather the character of the ball-and-socket, with a very shallow cup, than of the hinge-joint. But in proportion to the liability of any joint to dislocation, is usually the ease with which it may be brought into place again.

393. The action of any muscle in producing a change in the position of a movable bone on which it acts, is determined, in the first place, by the nature of the movement of which the bone is capable; and in the second, by the direction in which the power of the muscle is applied to it. The contraction of a straight muscle which is attached to a fixed point at one end, and to a movable point at the other, will obviously tend to draw the latter towards the former. Thus, the muscles which bend the fingers, lie in the palm of the hand and on the corresponding side of the fore-arm; while those that straighten the fingers are situated on the opposite side. But we often find that the direction of a muscle's action is changed, by the passing of its tendon through a pulley-like groove or loop; so that it draws the movable bone in a direction different from that of its fixed attachment. This is the case, for example, with some of the muscles that bend the toes; these being situated in the calf of the leg, would draw the toes upward, were it not that their tendons are carried beneath the bones of the heel, working in smooth pulley-like channels hollowed out in them; hence, when the muscle contracts, the tendons draw the ends of the toes towards the heel, and thus bend them.

394. We generally find that even movements of a simple character are performed by the combined action of several muscles; of which some may be considered as the principal, and others as assistants. Those which are principals in one movement may become assistants in another; and *vice versa*. Thus, if we wish to bend the wrist directly downward upon the fore-arm, we put in action, not only certain muscles whose tendency would be to produce this movement, but others which, acting by themselves, would produce a different motion. One of these would draw the wrist towards the thumb-side of the fore-arm; and the other towards the little-finger side; and they become the principal muscles in these movements respectively; but when they act together, their several tendencies to draw the wrist to the opposite sides counterbalance one another, and they simply assist the principal muscles in bending the wrist downward upon the fore-arm.

395. Almost every muscle has its *antagonist*, which performs an action precisely opposite to its own. Thus, by one set of muscles, termed *flexors*, the joints are bent; by a contrary set, the *extensors*, they are straightened. One set of muscles draws the arm or leg away from the central line of the body; another draws the limbs inward. One set, again, closes the jaws; and another opens them. In short, we shall find that probably every muscle in the human body has its antagonist in another muscle, or in some part of it. But we find an economy of muscular substance in some of the lower animals, where parts are to be usually kept in a particular position, and this is only to be changed occasionally and for a short time. Thus the valves of a clam, or an oyster, are kept apart, not by a muscle, but by an elastic ligament; but they are closed, when the animal is alarmed, and wishes to protect itself, by muscular action. In the same manner, the sharp claws of the Cat tribe are usually drawn in by an elastic ligament, that their points may not be worn away by rubbing against the ground; while they are forced outward by the action of a muscle provided for the purpose, when the animal desires to fasten them into its prey.

396. We commonly find that, in order to preserve the necessary form of the animal body, muscles are applied at a great mechanical disadvantage, as regards the exercise of their *power;* that is, a much larger force is employed than would suffice, if differently applied, to overcome the resistance. But we generally find that in this, as in other forms of lever action, what is lost in power is gained in time; and thus a very slight change in the length of a muscle is sufficient to produce a considerable movement.

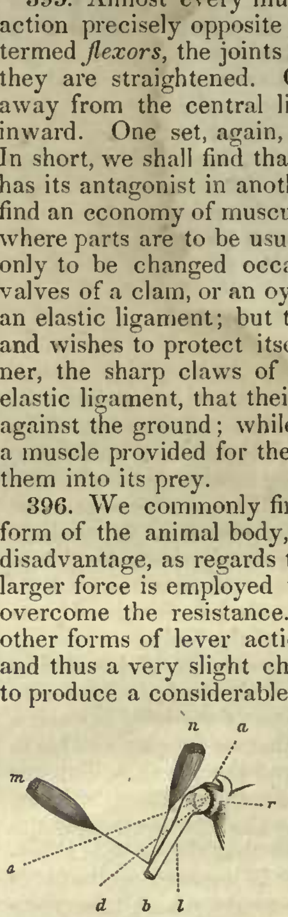


Fig. 59.

397. The first source of disadvantage results from the *direction* in which the muscle is attached to the bone. This is rarely at right angles to it; and, consequently, a considerable part of the power is lost. Thus, if the muscle *m* (fig. 59), whose force we shall suppose equal to 10, is fixed at right angles to the bone, *l*, whose extremity, *a*, is movable upon the point of support, *r;* its force of contraction will be most advantageously applied to overcome the resistance, and will draw the bone from the position *a b* into the direction *a c*, making it traverse a space which we shall also represent by 10. But if this muscle act obliquely on the bone, in the direction of the line *n b* for example, it will be quite otherwise; for it will then tend to draw the bone in the direction *b n*, and, consequently to make it approach the articular surface, *r*. But as this bears upon an immovable socket, and as the bone can move in no other way than by turning upon the point *r*, as upon a pivot, the contraction of the muscle to the same amount as before will carry the bone no further than into the direction *a d;* three-quarters of the force employed will thus be lost, and the resulting effect will be no more than one-fourth of that which the same power, applied perpendicularly to the bone, would have produced.

398. Now, in the animal body, we usually find that the muscles are inserted so obliquely, that their power is applied at a great disadvantage; but this disadvantage is rendered much less than it would have otherwise been, by a very simple contrivance—the very enlargement

§ 390. Where may the construction of the joints be well seen?—What is said of the two joints in the leg of mutton?—Describe the hinge-joint, and the ball-and-socket joint. 391. What examples are mentioned of these two joints?—How does the shoulder-joint differ from that of the hip? 392. How does dislocation take place in the different joints?—What is one of the most common dislocations? 393. How is the action of a muscle on a bone determined?—What is the obvious action of a straight muscle?—How is the direction of a muscle's action often changed?—What examples are given of this change of direction?—Describe the action of the muscles which bend the toes. 394. What is said of the combined action of muscles?—Describe the action of the various muscles exerted in bending the wrist.

§ 395. What are *antagonist* muscles?—What is said of flexor and extensor muscles?—How are the valves of a clam kept apart, and how closed?—How are the claws of a cat drawn in and forced out?—396. What is said of the loss of power in consequence of the mode in which muscles are usually applied? 397. Explain fig. 59, and explain why a muscle fixed at right angles to a bone will exert a greater force than if fixed obliquely. 398. How is the oblique insertion of the muscles rendered less disadvantageous than it would otherwise have been? Explain this by reference to figures 60, 61.

PLATE X.

ORGANS OF MOTION.—THE BONES.

FIGURE 1.——FRONT VIEW OF THE HUMAN SKELETON.

At the right half of this figure, the bones are represented in their natural connexions, and divested of all covering. At the left side, the joints are covered by their ligaments. The outer lines show the form of the body when covered with flesh.

THE HEAD.

a, The frontal-bone. *b*, The parietal-bone. *c*, The temporal-bone. *e*, The superior maxillary-bone. *f*, The malar-bone. *g*, The nasal bones. *h* The vomer. *i* The inferior maxillary-bone. *k*, The orbits. *l*, *l*, Sutures.

THE TRUNK.

1, 1, The spinal column. 2, The sternum. 3, 3, The ribs. 4, The os innominatum, or haunch-bone. 5, The sacrum.

THE SUPERIOR EXTREMITIES.

6, The clavicle. 7, Acromion process of the scapula, which articulates with the clavicle. 8, The humerus. 9, The elbow-joint. 10, The radius. 11, The ulna 12, Bones of the carpus. 13, Bones of the metacarpus. 14, The phalanges.

THE INFERIOR EXTREMITIES.

15, The hip-joint. 16, The femur, or thigh-bone. 17, The patella. 18, The tibia. 19, The fibula. 20, Bones of the tarsus. 21, Bones of the metatarsus. 22, Bones of the toes.

On the left side of the figure, *l* indicates the ligaments of the shoulder. *m*, Ligaments of the elbow. *n*, Ligaments of the wrist. *s*, Ligaments of the hip-joint *o*, Ligaments of the knee, and tendon of the extensor muscle of the leg. *p*, Ligaments of the ankle. *q*, Large vein and artery of the arm. *r*, Large vein and artery of the leg.

FIGURE 2.——SKELETON OF THE CAMEL.

The black ground in this and the two following figures shows the outline of the form when clothed with flesh.

a, The skull. *b*, The cervical vertebræ. *c*, The dorsal vertebræ.—The spinous processes of these vertebræ are much longer and larger than those of man, for the purpose of giving attachment to the strong muscles and ligaments by which the heavy neck and head are supported. *d*, The lumbar vertebræ. e, The sacrum. *f*, The caudal vertebræ, which compose the tail. *g*, The ribs. *h*, The scapula. *i*, The humerus. *j*, The fore-arm.—In this part, corresponding to the fore-arm of man, the two bones are united into a single one. *k*, Bones of the wrist or carpus. *l*, Bones of the metacarpus or hand. *m*, The phalanges. *n*, The femur, or thigh-bone, united to the bones of the pelvis. *o*, The patella, or knee-pan. *p*, The tibia; the two bones of the leg being united into one. *q*, Bones of the tarsus or ankle. *r*, Bones of the foot and toes.—In animals which do not possess fingers, the bones of the fore-arm, wrist, and hand are always few in number. Thus, in the camel, and in all herbivorous quadrupeds, the fore-arm has only one bone; the wrist, about four; the hand, only one, with sometimes the rudiment of another; while some species have two toes, and others only a single one. (§ 441, 446, &c.)

FIGURE 3.——SKELETON OF THE VULTURE.

vc, Cervical vertebræ, fifteen in number. *b*, Dorsal and lumbar vertebræ. *vs*, The sacrum. *vq*, Vertebræ of the tail. *st*, The breast-bone, or sternum. *cl*, The clavicle. *h*, The humerus. *o*, The two bones of the fore-arm. *ca*, Bones of the wrist, imperfectly developed. *ph*, Bones of the hand and fingers. *f*, The thigh-bone. *t*, The two bones of the leg. *ta*, The shank or ankle bones. (*See* § 454, 455.)

FIGURE 4.——SKELETON OF THE PERCH.

a, *b*, First and second dorsal fins. *c*, The caudal or tail-fin. *d*, The anal-fin. *e*, One of the ventral fins, which correspond to the legs. *f*, One of the pectoral fins, which are analogous to the arms. (§ 450 and following.)—The spinous processes of the vertebræ are long, and are connected with another set of bones, by which they are continued upward, so as to form the frame-work of the fins which arise from the back. The whole number of vertebræ is forty-two, of which twenty-one are dorsal, and twenty-one caudal or coccygeal. The number of pairs of ribs is the same as that of the dorsal vertebræ. (§ 416, 422.)

PRINCIPLES OF PHYSIOLOGY.

ORGANS OF MOTION.

(THE BONES)

Figure 1.

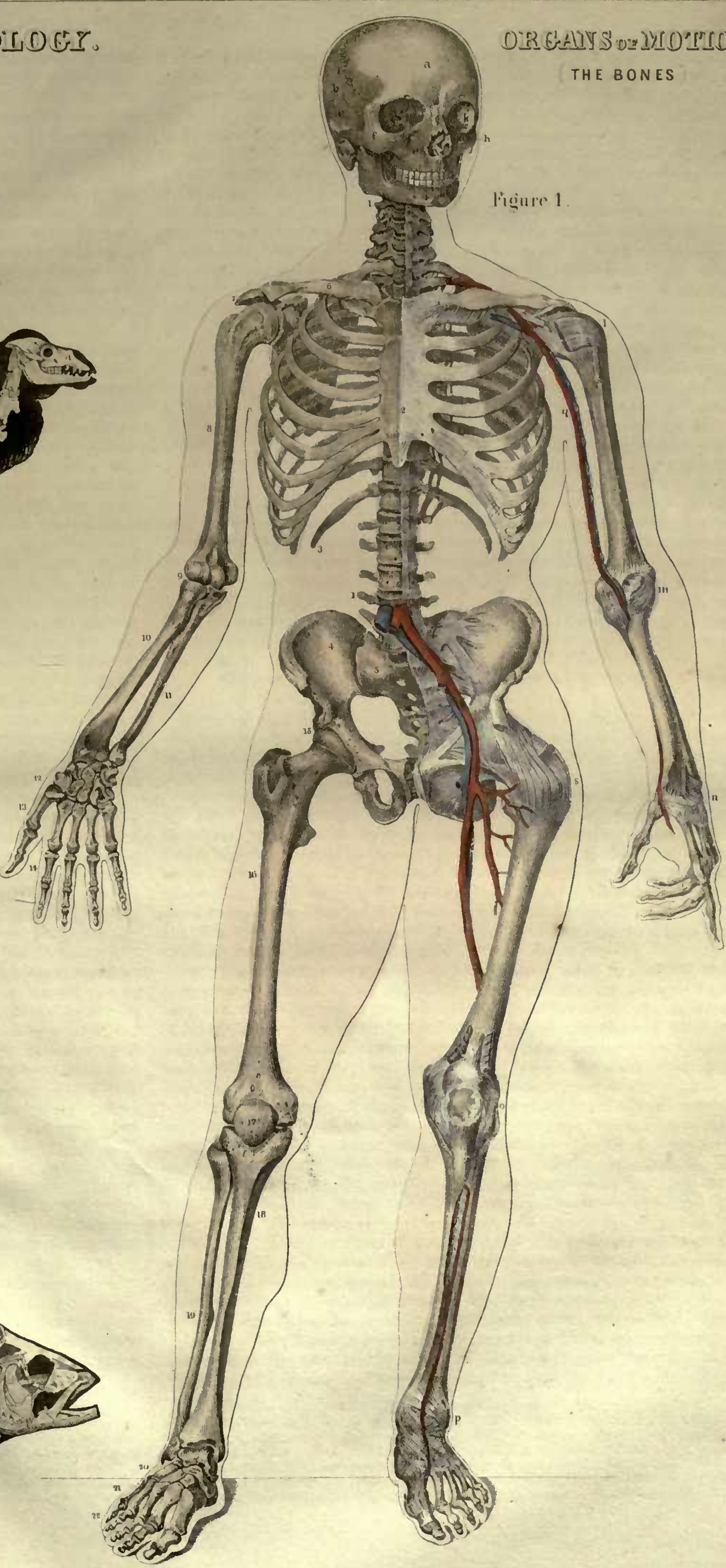


Fig. 2

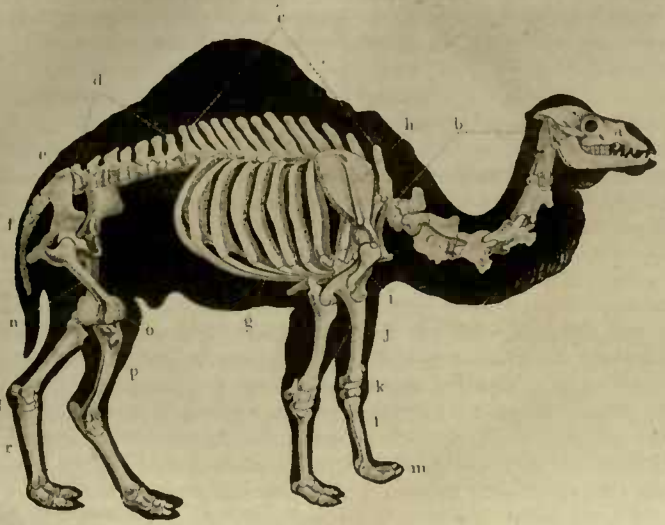


Fig. 3

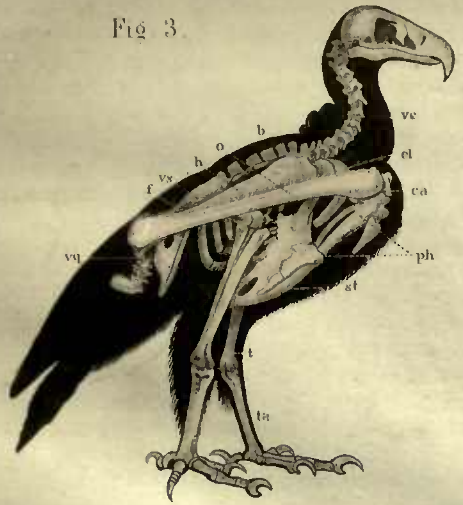
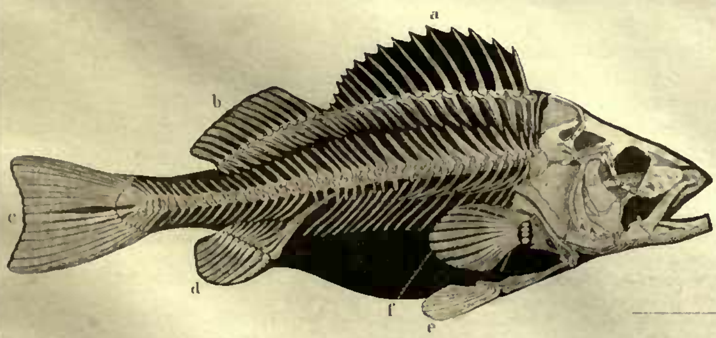


Fig. 4



Lith of Kellogg

Entered according to Act of Congress in the year 1850, by Kellogg & Comstock in the Clerk's Office of the District Court of Connecticut

Hartford Conn

of the bones at the joints, which is necessary to give them the required extent of surface for working over each other. Thus, let *r* and *o* (fig. 60) be two bones connected by a joint; and let the muscle *m*, which moves the lower bone upon the upper, be attached to the former, at *i*. Now, as this muscle acts almost precisely in the line of the bones themselves, almost all its power will be expended in drawing the lower bone against the upper. But by the enlargement of the ends of the bones, as seen in fig. 61, the direction of the tendon of the muscle *m*, is so changed, near its insertion, *i*, that the contraction of the muscle will cause the lower bone to turn upon the upper one with comparatively little loss of power. In the knee we find a still greater change of direction effected, by the interposition of a movable bone, the *patella* or *knee-pan*, in the substance of the tendon.

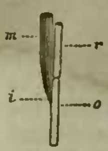


Fig. 60.

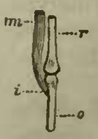


Fig. 61.

399. But the advantage or disadvantage with which the muscles act upon the bones depends, in great degree, upon the distance of their point of attachment from that of the point of support on which the bone moves, and from the point at which the resistance is applied. Every bone acted on by muscles may be regarded as a *lever*, having its fulcrum or point of support in the joint, its *power* where the muscle is attached to it, and its *weight* where the resistance is to be overcome; and the distances of the fulcrum from the power and the weight respectively, are termed the two arms of the lever. Now, the relative length of these two arms governs the force which is necessary to overcome a given resistance. Thus, in the Steelyard (fig. 62), the beam is divided into two arms, of unequal length, at the point of support or fulcrum, *a;* at the end of the short arm, *r*, hangs the body whose downward pressure we wish to determine; and on the other, *p*, there slides a weight, which will balance a greater or less amount of pressure at the opposite extremity, *r*, according as it is made to hang from a point which is more distant from the fulcrum or nearer to it; that is, according as the length of the power-arm of the lever is increased or diminished, that of the weight-arm remaining the same.

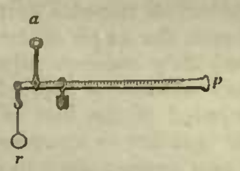


Fig. 62.

400. Now, in order that there may be an equilibrium, or balancing between the power and the weight, it is necessary that they should be inversely proportional to the lengths of their respective arms; that is, the power multiplied by the length of its arm, should be always equal to the weight multiplied by the length of *its* arm. Thus, to balance a certain resistance, *r* (fig. 63), equal to 10, and applied at the end of a lever, *a b*, whose length we shall call 20, it is necessary that a force, *p*, applied at the same point, and consequently at the same distance from the fulcrum, *a*, should also be equal to 10; but, if the power be applied at the point, *c*, which is at only half the distance from the fulcrum, *a*, it must be doubled in amount, or equal to 20—since it must be sufficient, when multiplied by its distance, 10, from the fulcrum, to make 200, which is the product of the resistance, 10, and its distance from the fulcrum, 20; and, in like manner, if the power be applied at *d*, where its distance from the fulcrum is only 2, its amount must be 100, in order that its product, with the distance at which it is applied, may be equal to 200. Hence, when a muscle is applied near the fulcrum, while the resistance is at a distance from it, its force must be proportionably greater.

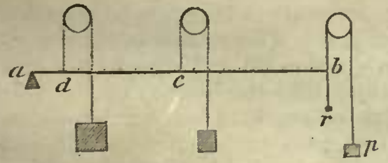


Fig. 63.

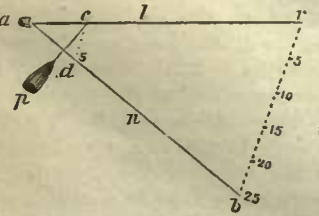


Fig. 64.

401. But this arrangement greatly increases the rapidity of the motion, which is the consequence of the muscular action. For, let us suppose that the muscle, *p* (fig. 64), acts upon the lever, *a r*, in such a manner that its point of insertion, *c*, traverses a space equal to 5 in one second; the extremity, *r*, of the lever will traverse a space equal to 25 in the same time, its distance from the fulcrum, *a*, being five times as great as that of the point *c* from the fulcrum. Hence, although, to raise a given weight at *r*, a power more than five times its amount must be applied at *c*, that power will raise the weight through a space five times as great as that through which itself passes in the same time. Thus, what is lost in power is gained in time; and the shortening of a muscle, small in amount, but effected with sufficient power, causes the raising of a weight through a considerable space.

402. We shall find that this is the case in regard to most of the muscular actions in the animal economy. Thus the fore-arm is bent upon the arm by a muscle, *d* (fig. 65), which arises from the top of the latter, and which is inserted at *e*, at a short distance from the elbow-joint. Hence its contraction to a very slight extent will raise the hand through a considerable space; but a proportional increase in its power will be required to overcome any resisting force in the hand. The arm is straightened again by an antagonist muscle, *f*, which lies on the back of the arm, and which is attached to a short projection made by one of the bones of the fore-arm *behind* the elbow. This muscle also acts at a similar disadvantage in regard to power, and advantage in point of time; in consequence of its point of attachment being so near to the fulcrum.

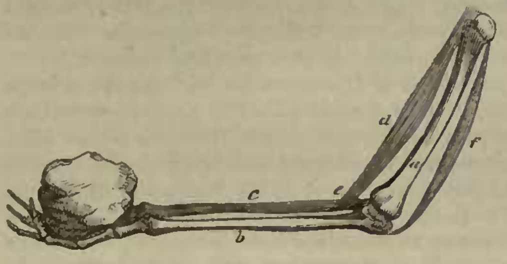


Fig. 65.

DESCRIPTION OF THE MOTOR APPARATUS OF MAN.

403. The skeleton of Man (plates 10, 11) is formed by the union of about two hundred and fifty bones, and is divided, like the body, into head, trunk, and members. The bones of these parts will now be separately described.

404. The *Head* is composed of two parts, the cranium or skull, and the face. The cranium is a bony case, of oval form, occupying the upper and back part of the head, and serving for the protection of the brain, which is lodged in its cavity. Its walls are made up of eight bones: the frontal, *a*, in the region of the forehead; the two parietal bones, *b, b*, which occupy the top and sides of the skull; the two temporal bones, *c, c*, which form the walls of the temporal region; the occipital-bone, *d*, at the back of the head; and the sphenoid, and the ethmoid, which assist in forming the floor of the cavity.

405. These bones are firmly united to each other by sutures, the character of which varies in different parts of the cranium, so that they are the better able to resist external violence. Thus, a blow upon the top of the arch formed by the parietal bones, will tend to separate them from each other and from the frontal-bone, and to force asunder their lower borders. Both these effects are resisted, by the peculiarity of the suture which unites different parts of the parietal-bone to its neighbors. For, at the top of the skull, the bones are firmly held together by the interlocking of the projections of each; while the lower edge of the parietal-bone is prevented from being driven outward by the overlapping edge of the temporal bones, which form, as it were, a buttress to the arch. This same contrivance prevents the temporal-bone from being driven inward by a blow on the side of the head, as it might otherwise have been.

406. In the base or floor of the cavity of the cranium are seen a number of apertures, which serve for the passage of the blood-vessels that supply the brain, and of the nerves that issue from it. One of these apertures, much larger than the rest, and situated in the occipital-bone, serves for the passage of the spinal cord; and on each side of this aperture there is a large bony projection from the under surface, termed the *condyle*, by which the skull rests upon the vertebral column, and is enabled to move forward or backward upon it. The

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§ 399. Upon what circumstances does the advantage or disadvantage with which the muscles act, depend?—Regarding the bone as a *lever*, where would be its fulcrum, its power, its weight?—What are the two arms of the lever?—Explain, by reference to fig. 62, how the relative length of these two arms governs the force necessary to overcome a given resistance? 400. What is necessary, in order that the power and weight may balance each other?—Explain this principle by reference to fig. 63.—What deduction is drawn from this in regard to a muscle? 401. Explain fig. 64, and show how, in the case of the muscles, what is lost in power is gained in time.

§ 402. Illustrate this principle still farther, by referring to fig. 65, and explaining the mode in which the fore-arm is bent and straightened. 403. Of how many bones is the human skeleton composed, and how is it divided? 404. What are the two parts of the head?—Describe the cranium.—Give the names and situations of the cranial bones. 405. How are these bones united, and how are they enabled to resist the effects of blows? 406. Describe the apertures of the cranium, the condyles, and the manner in which the head is balanced and kept upright on its pivot.—Where is this joint situated in other animals?

head is nearly balanced upon this pivot; nevertheless, the portion situated in front of the joint is more heavy than that which is situated behind it, and is, in consequence, not altogether counterpoised by the latter. Hence the muscles, which, arising from the back, and being attached to the occipital-bone, tend to draw the head backward, and thus to keep it upright, are more numerous and powerful than those which are situated in front of the vertebral column, and tend to draw the head downward and forward; and when the former are relaxed, as in a person sleeping upright, the head has a tendency to fall forward upon the chest. In no other animal is this joint situated so far forward as in Man. As we descend the scale, we find it nearer and nearer to the back of the skull; and, consequently, the whole weight of the head bears, not directly upon the spine, but upon the muscles and ligaments by which it is attached to the vertebral column.

407. On each side of the base of the cranium we observe a large rounded projection, termed the mastoid. To this projection (which we feel behind the lower part of the ear) is attached, on either side, a powerful muscle, which passes downward and towards the central line; so that the two muscles nearly meet at the bottom of the neck, where they are attached to the upper edge of the breast-bone. These muscles, acting together, serve to draw the head forward; but either of them, acting separately, will turn it to one side or the other. In front of these two projections of the skull we notice the opening of the external ear, which, like the different chambers of the internal ear, is excavated in a portion of the temporal-bone, which is termed *petrous*, from its very dense and stony character.

408. The *face* is formed by the union of fourteen bones; and presents five large cavities, which serve for the lodgment and protection of the organs of sight, smell, and taste. All the bones of the face, with the exception of the lower jaw, are completely immovable, and are firmly united to each other and to the bones of the cranium. The two principal are the *superior maxillary*, *e*, which form nearly the whole of the upper jaw, and which are connected with the frontal-bone, in such a manner as to contribute to the formation of the orbital cavities in which the eye is lodged, and of the nasal cavities which form the interior of the nose; they also constitute the front of the roof of the mouth; on the sides of the face, they articulate with the malar or *cheek* bones, *f*; and behind, with the palate bones, which form the back part of the roof of the mouth. These, in their turn, are united to the sphenoid.

409. The orbits, as we have already seen (§ 360), are two deep cavities, of a conical form—the base of the cone being directed forward, and the apex, or point of it, backward; the roof of these cavities is formed by a portion of the frontal-bone, and their floor chiefly by the superior maxillary. Their inside wall is formed by the ethmoid-bone, and by the small bone termed the lachrymal, in which is the canal for the passage of the tears into the nose (§ 361); and the outside wall is composed of part of the cheek-bone, and of a portion of the sphenoid; the latter also bounding the cavity at its deepest part, and containing the apertures which serve for the passage of the optic and other nerves that enter the orbit from the cranium. In the roof of the orbit, on its outer side, there is a broad shallow pit or depression, in which the lachrymal gland is lodged.

410. The greater part of the nose is formed by cartilages; so that, in the bony skull, the anterior opening of the nasal cavity is very large; and the bony portion of the nose, formed by the two small bones termed *nasal*, projects but slightly. The nasal cavity, divided in the middle by a vertical partition, into two *fossæ*, or excavations, is very extensive; at the upper part, it is hollowed out in the ethmoid-bone, the whole interior of which is made up of large cells; its floor is formed by the arch of the palate, which separates it from the mouth; behind, it extends as far as the back of the mouth, and communicates with the pharynx by two apertures termed the posterior nares. The partition between the fossæ is formed at the upper part by a plate that projects downward from the ethmoid-bone, and at the lower by a distinct bone called the *vomer* (or ploughshare), from its peculiar form; to the front edge of this last is attached a cartilage, which continues the partition forward into the soft projecting portion of the nose.

411. It is through the thin horizontal plate of the ethmoid-bone, which separates the nasal cavity from that of the skull, that the olfactory nerves make their way out from the former into the latter; they descend in numerous branches, for the passage of which, through the roof of the nose, this plate is perforated by a number of small apertures, which give it a sieve-like aspect; whence it is called the *cribriform* plate (from the Latin, *cribrum*, a sieve) of the ethmoid. The cavity of the nose is further extended, by its connexion with the *sinuses* or excavations that exist in the lower part of the frontal-bone (where they sometimes cause a considerable projection above the eyes), in the superior maxillary bones, and in the sphenoid. The surface of the mucous membrane which lines it, and on which its nerves are distributed (§ 317), is also extended, by being carried over a set of bones, termed spongy bones, which hang, as it were, from the side-walls of the cavity.

412. It is in the superior maxillary-bone that all the teeth of the upper jaw are implanted in Man; but, in the infant, this bone is composed of several pieces; and one of these pieces, termed the *inter-maxillary*-bone, remains permanently separate in most of the lower animals. The lower jaw of adult man, also, is composed but of a single piece; though this is divided in the infant on the central line, and the two halves remain separate in many of the lower animals. This bone has a general resemblance, in form, to a horse-shoe with its extremities turned up considerably. It is articulated with the temporal bones by a *condyle* or projecting head, with which each of these extremities is furnished; and this head is received into what is termed the *glenoid* cavity on the under side of the temporal-bone. In front of the condyle is another projection, or *process*, termed the coronoid, which serves for the attachment of one of the principal muscles that raise the jaw. These muscles are all attached near the *angle* of the jaw (or the point at which it bends upward), and they consequently act at a small distance from its fulcrum, while the resistance is applied at the furthest point. We are continually reminded of the loss of mechanical power which results from this, by our inability to exercise the same force with our front teeth, that we can employ with the back. Thus, when we wish to crack a nut, or to crush any hard substance between the teeth, we almost instinctively carry it to the back of the jaws, so as to be nearer the joint, and thus to receive more of the power of the muscle.

413. The general arrangement of the chief muscles of the face is seen in plate 12. The largest is the *temporal* muscle, the fibres of which arise from an extensive surface of the parietal and temporal bones, and then converge or approach each other, passing under the bony arch or *zygoma* (which is partly formed by a process from the temporal-bone, and partly by the malar or cheek-bone), to be attached to the coronoid process of the lower jaw. This muscle is of extraordinary power in those beasts of prey which lift and drag heavy carcases in their jaws; and in those which (like the hyæna) obtain their support by crushing the bones which others have left. It is assisted by the *masseter* muscle, which passes from the zygomatic arch and cheek-bone to the angle of the lower jaw, and also by other muscles. Besides these, the figure shows the ring-like muscle or sphincter which surrounds the opening of the eye, and serves, by its contraction, to close the lids; and also the similar muscle which surrounds the mouth and draws together the lips. The antagonists to these are several small muscles, which form the fleshy part of the face, and produce the various changes by which its *expression* is given. These muscles are more numerous in Man and the Monkey tribe than in any other animals.

414. Besides the twenty-two bones of which the skull is properly composed, we may reckon as belonging to it the four small bones which form part of the apparatus of hearing (§ 333); and also the *hyoid*-bone, which lies at the root of the tongue and at the top of the larynx. This last bone, in Man and the Mammalia generally, is connected with other parts of the skeleton only by ligaments and muscles; but in Birds it is connected with the temporal-bone, on each side, by a set of bony pieces jointed together like links in a chain.

415. The most important part of the *Trunk*, and even of the whole skeleton—that which serves to sustain the rest, and which varies the least in the different classes of Vertebrated animals—is the *spinal* or *vertebral column*, commonly called the *back-bone*. In Man, it consists of thirty-three pieces, called *vertebræ*, which are arranged into

§ 407. Where is the mastoid process, and what muscles are attached to it? 408. How many bones compose the face?—How many cavities has the face, and what do they contain?—Describe the superior maxillary, and the malar bones. 409. Describe the formation of the orbits. 410. Describe the nasal fossæ.—How is the partition between them formed? —Refer to plate 10. 411. Describe the cribriform plate of the ethmoid.—Why is it so called?—What are the sinuses, and the spongy-bones?

§ 412. What is said of the superior maxillary-bone? Describe the lower jaw-bone, its condyles, and the muscles which move it. 413. Refer to plate 12, and point out and describe the muscles of the face. 414. What other bones belong to the skull? 415. What number of vertebræ compose the spinal column?—How are they divided?

five divisions: 1. The *cervical* vertebræ, or vertebræ of the neck, of which there are seven; 2. The *dorsal* vertebræ, or vertebræ of the back, of which there are twelve; 3. The *lumbar* vertebræ, or vertebræ of the loins, of which there are five; 4. The *sacral* vertebræ, of which also there are five; and 5. The *coccygeal* vertebræ, of which there are four. All these vertebræ are separate at the time of birth; but the five sacral vertebræ are soon afterwards united into one piece, forming the bone which is termed the *sacrum;* and the coccygeal vertebræ are also commonly united into one piece, the *coccyx,* which is not unfrequently united, in old age, to the sacrum. In old persons, too, it is not uncommon for the lumbar vertebræ to be united together by bony matter deposited in their cartilages and ligaments.

416. The *dorsal* vertebræ are distinguished from the cervical and lumbar, as being those to which the ribs are attached. It is remarkable, that the number of the cervical vertebræ should be the same in all the Mammalia: the long-necked Giraffe having only seven; and the Whale, whose head seems to be joined to its body without the intervention of any neck, also having seven cervical vertebræ, although they are almost as thin as a sheet of paper. It is owing to the small number of joints in its neck, that the movements of the head of the Giraffe are far less graceful than those of the Swan and other long-necked Birds, in whom the number of cervical vertebræ is much greater. The following table shows the number of vertebræ in animals of different groups:

Mammalia.	Cervical.	Dorsal.	Lumbar.	Sacral.	Coccygeal.	Total.
Man, - - -	7	12	5	5	4	33
Long-tailed Monkey,	7	12	7	3	31	60
Lion, - - -	7	13	7	3	26	56
Long-tailed Opossum,	7	16	6	2	36	64
Long-tailed Ant-Eater,	7	16	3	6	40	72
Elephant, - -	7	20	3	4	27	61
Giraffe, - - -	7	14	5	4	18	48
Whale, - - -	7	15	9	1	27	59
Birds.						
Vulture, - - -	15	7	....	13	6	41
Swallow, - -	13	7	....	10	7	37
Turkey, - - -	14	7	....	15	6	42
Ostrich, - - -	18	9	....	19	9	55
Crane, - - -	17	10	....	15	6	48
Swan, - - -	23	11	....	16	8	58
Reptiles.						
Tortoise, - -	9	10	....	3	20	42
Monitor (Lizard), -	6	21	2	2	115	146
Python (Boa), - -	....	320	....	....	102	422
Rattle-Snake, -	....	171	....	....	36	207
Land Salamander, -	1	14	....	1	26	44
Fishes.						
Perch, - - -	....	21	....	....	21	42
Mackerel, - -	....	15	....	....	16	31
Salmon, - -	....	34	....	....	22	56
Cod, - - -	....	19	....	....	34	53
Conger Eel, - -	....	60	....	....	102	162
Electric Eel, - -	....	....	....	....	....	236
Shark, - - -	....	95	....	....	270	365

We see, from the above table, that it is by the multiplication of the coccygeal vertebræ, that the tail is prolonged in those animals which possess it. In fact, it is only in Man, and in those of the Ape tribe which approach nearest to him, that the number is as low as four.

417. The essential character of the *vertebræ* consists in being perforated by an aperture, which, when several vertebræ are united together, forms a continuous tube or canal for the lodgment of the spinal cord. This character is usually lost, however, in the coccygeal vertebræ; which are so much contracted and simplified, as to contain no aperture. The purpose of the division of the spinal column into so large a number of separate bones, is obviously to allow of considerable freedom of motion, by a slight change of place in the individual parts; while any sudden bend, which would be injurious to the spinal cord, is avoided. Each vertebra consists of a solid *body* (plate 11, fig. 4), which is situated in front of the spinal canal, in Man, but below it, in animals whose back has a horizontal position, and which serves to give solidity to the structure—and of *processes* or projections, that serve to form the spinal canal, and to unite the vertebræ to each other. In Man, and other warm-blooded animals, the two surfaces of the body are nearly flat, and are parallel to each other; and they are united to the corresponding surfaces of the neighboring vertebræ by a disc of fibro-cartilage, which extends through the whole space that intervenes between them, and which, being firmly adherent to both, prevents them from being far separated from each other.

418. But, in Reptiles and Fishes, a different plan is adopted. In the animals of the former class, particularly in Serpents, we find one surface of each vertebra *convex* or projecting, and the other *concave* or hollowed out; and the convex surface of each vertebra fits into the concave surface of the next, in such a manner that the whole spinal column becomes a series of ball-and-socket joints, and is thus endowed with that flexibility which is essential to the peculiar movements of these animals. In Fishes, *both* surfaces are concave; and between each vertebra there is interposed a bag containing fluid, and having two convex surfaces, over which those of the vertebræ can freely play. Extreme facility of movement is thus given to the spinal column; but its strength is proportionally diminished. It is to be remembered, however, that strength is not required in the bony frame-work of animals whose bodies, instead of being supported upon four fixed points, are buoyed up in every part by a liquid of nearly the same density with themselves. The extreme flexibility of the spine of Fishes enables them to propel their bodies by the movements of the hinder portion and tail, from side to side; their members, or pectoral and ventral fins (plate 10, fig. 4) being but little used, except for influencing the direction of their motion. And thus we see that in fishes, as in the Leech and Earth-worm, the propulsion of the body being accomplished by the movements of the trunk itself, its skeleton. (internal in the one case, external in the other) is left in the soft condition, which it has in all at an early period; while in the higher classes—Birds and Insects, for example—it undergoes great consolidation, its various pieces being so knit together as to make the trunk almost immovable; the extremities being so developed, and being furnished with muscles so powerful, that the function of locomotion is entirely committed to them.

419. This knitting together is partly accomplished by means of projections or processes from the several vertebræ, which are united to one another by muscles and ligaments. Of these processes there are seven in Man from each vertebra. One of these, termed the spinous process (*b*, plate 11, fig. 4), projects directly backward; and thus is formed the prominent ridge on the back, in which the ends of these projections can be distinguished. The spinous processes serve, in Man, to give attachment to the muscles, by which the trunk and head are kept erect; in Animals whose spine is horizontal (plate 10, fig. 2, as the Camel), they are generally much longer, in order to give firm attachment to the muscles and ligaments which support the head; and in Fishes they are greatly prolonged, in order to increase the surface, by the stroke of which from side to side the body is propelled through the water. On each side of the vertebra is a process, which is called *transverse;* this serves for the attachment of the ribs to the vertebra. And lastly, from the upper and under side of each vertebra, two *articulating* processes project, which lock against each other in such a manner as to prevent the movements of the vertebræ from being carried to an injurious extent. These processes are peculiarly long in Birds, where they almost completely check the movements of the dorsal vertebræ; thereby giving to the trunk that firmness which is required for the attachment of the muscles of the wings. The portions of bone which pass backward from the body to the transverse processes, and form the side wall of the spinal canal, are called the *arches* of the vertebræ. These are the parts first formed. On the under edge of each there is a notch which corresponds with one in the upper side of the next; in such a manner that, when two vertebræ are placed together, a complete foramen or aperture is formed, which serves for the passage of the nerves that are given off from the spinal cord.

420. The vertebral column of Man is disposed in a double curve,

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§ 416. How are the dorsal vertebræ distinguished from the others?—What is remarkable in regard to the cervical vertebræ?—Why are the movements of the head of the Giraffe more awkward than those of the Swan?—State the number of vertebræ in some of the animals in the table.—How is the tail of animals prolonged? 417. In what does the essential character of vertebræ consist?—Which vertebræ possess no aperture?—Why is the spinal column divided into so large a number of bones?—Describe the parts of each vertebar, referring to plate 11, figs. 4, 5.—How are the bodies of the vertebræ united to each other?

§ 418. How are they united in Reptiles, and how does this mode of union increase the flexibility of those animals?—How is the vertebral column of Fishes constructed, and why is its strength sacrificed to its flexibility?—Why is the skeleton left soft in the lower animals, and why is it consolidated in the higher? 419. Describe the processes of the vertebræ, and their uses.—Why are the spinous processes longer in the Camel than in Man?—Why are they prolonged in Fishes?—Where are the articulating processes situated, and what is their use?—What peculiarity do they possess in Birds?—Describe the arches and foramina of the vertebræ. 420. Why is the spinal column of Man disposed in a double curve?—Why is a man taller in the morning than at night?

as seen in plate 6, the effect of this is to diminish the shock that would be produced by a sudden *jar*—such as when a man jumps from a height upon his feet. If the vertebral column had been quite straight, this *jar* would have been propagated directly upward from the pelvis to the head, and would have produced very injurious effects upon the brain; but by means of the double curvature, and the elasticity of the ligaments, &c., which hold together the vertebræ, it is chiefly expended in increasing, for a moment, the curves of the spine, which thus acts the part of a spring. The constant pressure of the head and upper part of the trunk has a tendency to increase these curves permanently, and thus to diminish the height of the body. The elasticity of the intervertebral substance, however, causes it to recover, during the time when the body is in the horizontal posture, the form it had lost by pressure in the upright position; and thus a man is taller, by half an inch or more, when he rises in the morning, than he was when he lay down the night before.

421. The first vertebra of the neck, termed the *atlas*, is much more movable than the rest, and differs considerably from them in its form. It is destitute of *body;* but it has a broad smooth surface on either side, on which rest the condyles of the occipital-bone of the skull, in such a manner that the head is free to *nod* backward and forward. The atlas itself turns upon a sort of pivot, formed by an upward projection from the next vertebra, which is termed the *axis;* this projection, called, from its form, the *processus dentatus* (or tooth-like process), occupies the place of the body of the atlas; and, by the rotation of the atlas around it, the movements of the head from side to side are accomplished. Wherever great freedom of motion is permitted, displacement or dislocation is necessarily more easy; and, accordingly, we find that the atlas and axis can be more easily separated from each other than can any other two vertebræ. This dislocation may be produced by violence of different kinds; thus, if the head be suddenly forced forward, while the neck is held back, the tooth of the axis may be caused to press against the spinal cord, and thus to interrupt or completely check its functions. Or, again, if the weight of the body be suspended from the head, and especially if it be thrown upon it with a jerk, the two vertebræ are likely to be dragged asunder, and the spinal cord to be stretched or broken. This is sometimes the immediate cause of death in hanging; and it has not unfrequently occurred when children have been held in the air, by the hands applied to the head—a thing often done in play, but of which the extreme danger should prevent its ever being practised. Any serious injury of the spinal cord in this region must be immediately fatal, for the reason formerly stated (§ 272), that it causes the suspension of the motions of respiration.

422. The number of the ribs which are attached to the bodies and transverse processes of the dorsal vertebræ, is, in the human species, twelve on each side.* The number in different animals may be judged of by that of the dorsal vertebræ in the table already given (§ 416); since it is the attachment of the ribs that makes the essential difference between the *dorsal* vertebræ and the cervical or lumbar. The other extremity of each rib is connected with a cartilage, which is a sort of continuation of it; in Birds, the cartilages of the ribs are ossified or converted into bone. The cartilages of the first seven ribs (in Man), which are termed the *true* ribs, are united to the *sternum* or breast-bone, which forms the front wall of the thorax. The cartilages of the five lower ribs are not directly connected with this, and they are hence called *false* ribs; those of three of them, however, are connected with the cartilage of the seventh rib; and the other two ribs, being completely unattached at their anterior ends, are termed *floating* ribs. The *sternum* or breast-bone is flat, and of simple form in Man; but it is much larger in many other animals. In those which have need of great strength in the upper limbs, such as Birds, Bats, and Moles, it is not only increased in breadth, but is furnished with a projecting keel or ridge, for the attachment of powerful muscles. In the Turtle tribe, on the contrary, it is very much extended on the sides, so as to afford, with the ribs, a complete protection to the contained parts.

423. We have next to consider the structure of the *members* or appendages, which are attached to this central frame-work. These are spoken of as *superior* and *inferior*, when treating of Man, whose erect posture places one pair above the other. But when the ordinary *Quadrupeds* are alluded to, they are termed *anterior* and *posterior*, one pair being in front of the other. Each member consists of a set of movable bones, which serve as levers; but the socket in which the first of these works, is formed by a bony frame-work, which is connected more or less closely with the spinal column. This frame-work, in the upper extremity, consists of the *Scapula* or blade-bone, and the *Clavicle* or collar-bone. In the lower extremity, it is formed by a set of bones, the union of which with the sacrum completes the *Pelvis* or basin, which is found at the bottom of the spinal column.

424. The *Scapula* is a large flat bone, which occupies the upper and external* part of the back. Its form is somewhat triangular; and at its upper and external angle, is a broad but shallow cavity, destined to receive the head of the humerus or arm-bone. Above this cavity is a large projection, termed the *acromion process*, which is united by ligaments, &c., with the external end of the clavicle, and thus forms the bony eminence that we feel at the top of the shoulder. A little internally to this we find another process, the *coracoid*, which only serves in Man for the attachment of certain muscles, but which in Birds is developed into a distinct bone. The back surface of the scapula is divided into two by a projecting ridge or keel, which gives a more extensive and firmer attachment to the muscles that arise from it. The scapula is never deficient in animals that possess a superior extremity, though sometimes it is very narrow. The muscles attached to it are chiefly those which draw the arm upward, and which turn it on its axis. In Man, their actions are very numerous and varied; but in animals that only use their extremities for giving motion to the body, the muscular apparatus is much simpler, and the scapula is narrower. This is particularly the case in Birds, the *raising* of whose wings in flight is an action that requires very little power, though for their *depression* or pulling-down, great muscular force is needed.

425. The *Clavicle* is a rounded bone, attached at one extremity to the acromion process of the scapula, and at the other to the top of the sternum. Its principal use is to keep the shoulders separate; and we accordingly find it strongest in those animals, the actions of whose superior extremities tend to draw them together; while it is comparatively weak, or altogether deficient, in the animals, the actions of whose limbs naturally tend to keep them asunder. Thus, in Birds, the violent drawing down of whose wings, in flight, would tend to bring the shoulders together, if they were not prevented, there is not only a strong clavicle, but usually a second bone, having a similar function; while, in the horse and other animals, the bearing of whose weight on their fore-legs would tend rather to separate the shoulders than to bring them together, the clavicle is deficient.

426. The scapula is connected with the central frame-work of the skeleton by various muscles which pass towards it from the spinal column and ribs; and which serve alike to fix it, and to assist in sustaining the weight which it sometimes has to bear. In Man, these are numerous, and their actions are various; since the scapula is left very movable in him, that the actions of the arm may be more free. In Quadrupeds, it is generally more fixed; and the trunk is slung from it, as it were, by a muscle (the *serratus magnus*) of moderate thickness in Man, but in these animals of great strength, which passes from the scapula to be attached to the ribs.

427. The *superior* or *anterior member* itself is divided into three principal portions—the arm, fore-arm, and hand. The arm is supported by a single long and cylindrical bone, which is called the *humerus;* this has a large rounded head, which is received into the glenoid cavity of the scapula; and, at the bottom, it assists in forming the hinge-joint of the elbow. The muscles which move it are for the most part attached to its upper third; and the chief of them are the *pectoralis major*, which rises from the sternum and cartilages of the ribs, and consequently draws the arm forward, inward, and downward (when it is raised); the *latissimus dorsi*, which rises from the spinal column and hinder part of the ribs, and consequently draws the arm backward, inward, and downward; and the *deltoid*, which arises from the upper edge of the clavicle, and from the ridge of the scapula,

§ 421. Describe the atlas.—The axis, and its tooth-like process.—How may the atlas and axis be separated, and what are the effects of this dislocation?—What is said of the danger of raising children by the head? 422. What is the number of the ribs in Man?—How are they divided, and how attached?—Describe the sternum.—How does this bone differ in form in different animals, and why? 423. What is said of the structure of the *members?*—What of the frame-work by which they are connected with the trunk?

§ 424. Describe the scapula and its processes?—What is said of the muscles attached to it? 425. Describe the clavicle and its uses. 426. What is said of the muscles which connect the scapula with the trunk? 427. What are the three portions of the superior member?—Describe the bone of the arm, and the muscles attached to it.—What are the actions of the *pectoralis major*, the *latissimus dorsi*, and the *deltoid muscles?*

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* It is scarcely necessary to state, that the common notion respecting the deficiency of a rib on one side of the body of Man is a popular error.

* The term *external* is continually used, in Anatomy, to describe the parts furthest removed from the *central* or *median line* of the body.

PLATE XI.

ORGANS OF MOTION.—THE BONES.

FIGURE 1.—POSTERIOR VIEW OF THE HUMAN SKELETON.

THE HEAD.

a, The frontal-bone. *b*, *b*, The parietal bones. *c*, The left temporal-bone. *d*, The occipital-bone.

THE TRUNK.

1, 1, 1, Spinous processes of the vertebræ. *t*, *t*, *t*, Transverse processes of the vertebræ. 2, 2, The ribs. 3, The os innominatum, showing its three parts, viz: *a*, the ilium; *b*, the ischium; *c*, the os pubis. 4, The sacrum. 5, The coccyx.

THE SUPERIOR EXTREMITIES.

6, The scapula. 7, Acromion process of the scapula. 8, The clavicle. 9, Head of the Humerus placed in the glenoid cavity of the scapula. 10, Shaft of the humerus. 11, 12, Internal and external condyles of the humerus. 13, The olecranon process of the ulna, which articulates with the pulley-like surface at the lower end of the humerus, forming the elbow-joint. 14, Shaft of the ulna. 15, Shaft of the radius. 16, Lower extremity of the radius, which articulates with the bones of the carpus. 17, Bones of the carpus. The first row consists of four bones, viz: *a*, the scaphoid-bone; *b*, the semi-lunar-bone; *c*, the cuneiform-bone; *d*, the pisiform-bone. The second row consists of four bones, viz: *e*, The trapezium. *f*, The trapezoid-bone. *g*, The os magnum. *h*, The unciform-bone.—18, 18, Bones of the metacarpus 19, 19 20, 20, 21, 21, First, second, and third ranges of finger bones.

THE INFERIOR EXTREMITIES.

22, Head of the femur, placed in the acetabulum or cotyloid cavity of the haunch-bone. 23, 24, Projections called trochanter major and minor, to which the muscles of the hip are attached. 25, Shaft of the femur. 26, 27, External and internal condyles of the femur. 28, Upper extremity of the tibia, which articulates with the femur. 29, Shaft of the tibia. 30, The internal malleolus, a projection of the tibia which forms the inner ankle. 31, The fibula. 32. External malleolus, a projection of the fibula which forms the outer ankle. 33, Bones of the tarsus. 34, Bones of the metatarsus. 35, Bones of the toes. The ligaments of the various joints are seen on the left side of this figure.

FIGURE 2.—GROUP OF BONES.

The bones here represented are so situated that they cannot be distinctly seen in the large figure. *a*, The sphenoid-bone. *b*, The malar-bone. *c*, The ethmoid-bone. *d*, One of the spongy bones. *e*, The vomer. *f*, The lachrymal-bone. *g*, The nasal bones. *h*, The palate-bone.

FIGURE 3.—THE OCCIPITAL-BONE,

DETACHED FROM THE SKULL.

a, The foramen magnum or occipital hole, which gives passage to the spinal cord. *b*, *b*, Condyles, which rest upon the vertebral column. (*See* § 406).

FIGURE 4.—A DORSAL VERTEBRA.

a, The body of the vertebra. *b*, The spinal foramen. *c*, *c*, Articulating processes. *d*, *d*, Transverse processes. *e*, Spinous processes.

FIGURE 5.—A LUMBAR VERTEBBA,

TO SHOW THE GREATER THICKNESS AND STRENGTH OF ITS BODY AND PROCESSES.

FIGURE 6.—THE LOWER JAW.

a, The condyle, which articulates with the temporal-bone. *b*, The coronoid process. *c*, The ramus. (§ 412).

FIGURE 7.—THE BONES OF THE FOOT,

SEEN UPON THE UPPER SURFACE.

a, The os calcis, or heel-bone. *b*, The astragalus, which articulates with the lower end of the tibia. *c*, The cuboid-bone. *d*, The scaphoid-bone. *e*, *e*, *e*, Cuneiform. bones.

FIGURE 8.—THE KNEE-JOINT,

WITH ITS INTERNAL LIGAMENTS, THE PATELLA BEING REMOVED.

a, *a*, The condyles of the femur, covered with cartilage. *b*, *b*, The two semi-lunar cartilages, which form cup-shaped depressions for the reception for the condyles. *c*, The anterior crucial ligament which passes from the tibia to the femur.

FIGURE 9.—A SECTION OF THE HIP-JOINT.

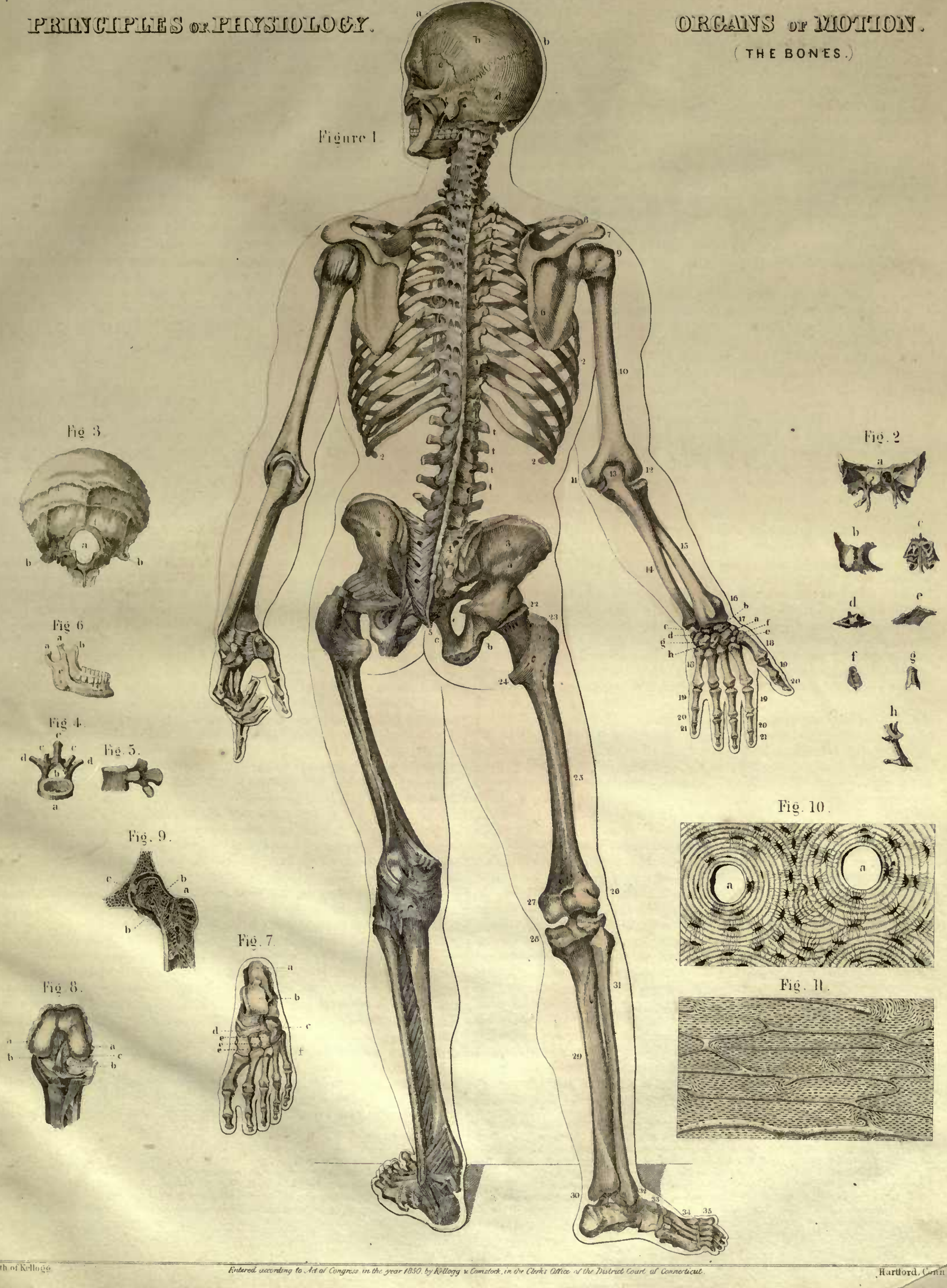
a, The head of the femur. *b*, *b*, The capsular ligament, embracing the cavity of the hip-bone and the head of the femur, and keeping both bones firmly together. *e*, A round ligament attached to the inside of the cavity and to the head of the femur.

FIGURES 10 AND 11.

These figures are designed to show the minute structure of bone. Figure 10 represents a cross-section of bone, highly magnified. *a*, *a*, Orifices of small tubes, called, from their discoverer, Haversian canals. They usually run in the direction of the length of the bone, the membrane lining the hollow of which is prolonged into their canals. This membrane contains innumerable small blood-vessels, and the interior of the bone is thus supplied with blood. Around each of the Haversian canals are seen concentric circles of small dark spots, which are found to be flattened cavities or bone-cells, from which proceed numerous minute tubules. These open into the sides of the Haversian canals, and communicate from one bone-cell to another, thus transmitting the nourishment with which they are supplied by the blood-vessels throughout the substance of the bone. Figure 11, represents a longitudinal section of bone, highly magnified, showing the Haversian canals seen lengthwise, their connexion with each other, and the direction of the bone-cells. These figures are from *Hassall's Microscopic Anatomy*.

PRINCIPLES OF PHYSIOLOGY. **ORGANS OF MOTION.**

(THE BONES.)



Lith of Kellogg

Entered according to Act of Congress in the year 1850, by Kellogg & Comstock, in the Clerk's Office of the District Court of Connecticut.

Hartford, Conn.

and is the chief muscle concerned in raising the arm. The first of these forms the principal part of the fleshy mass upon the front of the chest, and is the muscle which is so remarkably developed in Birds. It forms also the front boundary of the *axillary space*, or hollow of the arm-pit, the hinder boundary of which is formed by the second muscle. This space, of which we can distinctly feel the front and back walls, when we raise the arm a little from the side, contains the large vessels and nerves proceeding to the arm, and also a number of lymphatic glands. The deltoid muscle forms the thick fleshy mass on the top of the shoulder, and the upper part of the outside of the arm.

428. In the fore-arm of man there are two long bones, termed the *Radius* and *Ulna;* which lie nearly parallel to each other. The radius is on the outer or thumb side of the fore-arm; and the ulna on the inner. They are connected with one another, not only by ligaments at their extremities, but by a strong fibrous membrane that passes between their adjacent edges, along their entire length. Nevertheless, they have considerable freedom of motion, not only upon the humerus, but upon each other. It is by this peculiar conformation that the fore-arm possesses the power of rotation on its own axis, by which either the palm or the back of the hand may be turned upward. The ulna is connected with the humerus, at the elbow, by means of a hinge-joint, into which the radius does not enter. But it is the radius with which the hand is connected at the wrist, by a kind of ball-and-socket joint, the ulna having no direct share in this articulation. Hence, while both bones move together, in bending or straightening the elbow, we can make the radius roll round the ulna, carrying the hand with it. This movement is one of very great importance, in rendering the hand capable of a very great variety of uses, to which it would be otherwise inapplicable. It is only among the higher orders of Quadrupeds, however, that it can possibly be executed; for, in the lower, the two bones are united more or less completely into one, or are articulated in such a manner as to be incapable of rotation.

429. The fore-arm is bent upon the arm, chiefly by muscles that lie upon the front of the latter; of these, the principal is the *biceps* or two-headed muscle, which arises from the coracoid process of the scapula, and from the top of the glenoid cavity, and is inserted into the radius a little in front of the elbow, forming a great part of the fleshy mass in front of the arm (plate 12). The arm is straightened again by a large muscle, the *triceps*, or three-headed muscle, which arises from the back of the humerus and scapula, and passes down to be inserted into a projection of the ulna, behind the elbow-joint, forming the fleshy mass at the back of the arm. The muscles which rotate the fore-arm either arise from one of its bones, and pass obliquely to the other, or from the lower end of the humerus, and pass to the fore-arm.

430. The *Hand* is anatomically divided into three portions—the *carpus*, *metacarpus*, and *fingers*. The carpus, which is the portion nearest the wrist-joint, is composed of eight small short bones, which are firmly united to each other by ligaments, but yet have a certain degree of motion permitted them; these are arranged in two rows, of which one has a rounded surface, and enters into the formation of the wrist-joint; while the other has a series of shallow pits, to receive the rounded heads of the metacarpal bones. These last almost precisely resemble the bones of the fingers, and in the skeleton might be mistaken for their first joints; but, with the exception of that of the thumb, they are all united to each other by ligaments and muscles, so as to form the compact frame-work which gives support to the palm of the hand. The metacarpal bone of the thumb is much more free in its movements; and it is chiefly by an alteration in its direction, that the thumb can be *opposed* to the fingers. These are formed by a series of small bones, which are termed the *phalanges*, of which there are only two in the thumb, while there are three in the fingers. They are bent on each other chiefly by the action of the muscles that occupy the front of the fore-arm; and they are extended or straightened by others that lie along its back. These terminate in long tendons, which are bound down at the wrist by a fibrous band, that stretches between the bony processes on either side, and is termed the *annular* (or ring-like) ligament. The tendons then spread asunder in the hand, and pass on to be inserted into the bones of the several fingers, being rëinforced by a set of small muscles that arise from the hand itself.

431. When we consider the superior extremity of Man as a whole, we remark that the several levers, which are joined end-to-end to form it, diminish progressively in length. Thus, the arm is longer than the fore-arm; the latter is longer than the wrist; and each of the phalanges is longer than the one which succeeds it. The purpose of this arrangement is very evident. The numerous joints, in the neighborhood of each other, which we see towards the extremity of the limb, permit its several portions to change their place in various ways, so as to accommodate themselves to the form of the body which it is desired to grasp; while the long levers formed by the arm and fore-arm allow the place of the entire hand to be rapidly changed to a considerable extent. It is principally by the movements of the humerus upon the scapula, that the direction of the limb is given; the bending or straightening of the limb regulates its length; while the movements of the thumb and fingers are concerned in its particular application.

432. The hand of Man is distinguished from the extremity of most Quadrupeds by its possession of an *opposable thumb;* that is, of a finger which can be made to act in a direction opposite to that of the rest. But, among the Apes and Monkeys, we find this peculiarity not only in the superior extremity, but also in the inferior; whence these animals are said to be *Quadrumanous* or four-handed, while Man is *Bimanous*, possessing two hands only. It must not be supposed, however, that Apes and Monkeys are superior in this respect to Man; for they possess this distinguishing character in a much less striking degree than he does. All the four extremities of Apes and Monkeys possess the power of grasping, but they are all used also for support; and we find that, in consequence of the shortness of the thumb and great-toe, the grasping power is very inferior to that which we possess. But, of the four extremities of Man, one pair is adapted for support, and the other for *prehension* or grasping; and this by the length and mobility of the thumb, which is capable of being brought into exact opposition to the extremities of all the fingers, whether singly or in combination. But even in those Quadrumana which most nearly approach Man, the thumb is so short and weak, and the fingers so long and slender, that their tips can scarcely be brought near to each other, and then with only a slight degree of force; hence, although completely adapted for clinging round bodies of a certain size, such as the small branches of trees, &c., the extremities of the Quadrumana can neither seize very minute objects with that precision, nor support large ones with that firmness, which is essential to the dexterous performance of a variety of purposes for which the hand of Man is admirably suited.

433. In many of the inferior Mammalia, whose extremity is adapted for *support* only, we find each row of phalanges consolidated into two bones, or even into one. This is the case, for example, in the Ruminant Quadrupeds, as the Camel (plate 10), and in the Horse. Such an arrangement obviously increases the firmness of the limb; but it altogether deprives it of prehensile power. In other instances, we find the number of bones in the hand increased, but all of them inclosed in one envelope, so that the fingers are not separate. This is the case with many aquatic animals—such as the Whale tribe among Mammalia, Turtles among Reptiles, and Fishes in general—in which the hand is made to serve as a fin or paddle. In most of these, the bones of the arm are very short; and the movements of the extremity are chiefly confined to the wrist-joint.

434. The structure of the lower extremities has a very great analogy to that of the upper; and the principal differences to be remarked between them are such as are necessary to give to the former more solidity, at the expense of freedom of motion, and to make them organs of locomotion, instead of organs of prehension. Here, too, we have a bony frame-work, for the purpose of connecting the limb itself with the spine; and as the weight of the body is constantly thrown upon the lower extremities, this frame-work is much more firmly attached to that of the trunk, than is the case with that which supports the arms. It consists on each side of a bone, which, in the adult state, is single; though, at an early age, it is composed of three distinct pieces. This bone is closely connected with the sacrum behind, and in front it

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§ 428. What are the bones of the fore-arm.—Describe their relative situations and their joint actions. 429. What are the principal muscles which act upon the fore-arm, and how do they operate respectively? 430. How is the hand divided?—Describe the bones of the carpus.—Of the metacarpus.—Of the fingers.—How are the phalanges bent?—Describe the mode in which the tendons of the muscles are distributed to the fingers.

§ 431. What is said of the superior extremity of Man as a whole?—What is the purpose of this arrangement? 432. How is the hand of Man distinguished from the extremities of Quadrupeds?—In Apes and Monkeys, where is this peculiarity also found?—What names are given to these animals and to Man, from this difference?—Are Apes superior in this respect, to Man? and why not? 433. What modifications of the phalanges are found in some of the lower animals? 434. How does the structure of the lower extremities differ from that of the upper, and why?—Describe the construction of the pelvis, and the mode in which the lower limbs are attached to it.

meets with its fellow, in such a manner as to form a sort of basin, termed the *pelvis.* The spreading sides of this, formed by the *iliac* bones, afford support above to the viscera contained in the abdomen; and they give attachment by both surfaces to large muscles, by which the thigh-bone is moved; and, by their edges, to large expanded muscles that pass upward to the ribs and sternum, and form the wall of the abdomen. Below this spreading portion we find the articular cavity, which is so deep as to be almost a hemisphere, when completed by its cartilaginous border. The movements of the thigh-bone are, consequently, more limited than those of the arm; but it is much less liable to displacement.

435. The thigh, like the arm, is supported by a single bone, which is named the *femur.* Its upper extremity is bent at an angle; and its rounded head is separated from the rest by a narrow portion, which is termed its neck. At the point where this neck joins the shaft of the bone, there are two large projections—one on the outside, the other on the interior side—which can be felt beneath the skin; and these serve to give attachment to the muscles by which the thigh is moved. Of these muscles, one descends from the lumbar vertebræ; and this, with another that rises from the upper expanded surface of the pelvis, passes down over the front border of the pelvis, and is attached to the smaller or interior of the projections just mentioned. These, with the assistance of other muscles, raise or draw forward the thigh—an action which does not require, in Man, to be performed with any great force. The muscles which draw back the thigh, on the other hand, arise from the under surface and back of the pelvis, where they form a very thick fleshy mass; and they pass to the larger and external projection, and to a ridge which runs down the thigh-bone. Other muscles, which arise from the lower border of the pelvis, serve to rotate the thigh upon its axis. The lower end of the thigh-bone spreads into large *condyles,* on which the large bone of the leg moves backward and forward. The knee is a good example of a pure hinge-joint, all its movements being restricted to one plane.

436. The leg, although containing two bones like the fore-arm, does not possess the peculiar movement which characterizes it. One of these bones, called the *tibia,* is much larger than the other, which is called the *fibula;* and it is the former alone which rests upon the thigh-bone, and which also gives the chief support to the foot, so that no movement of rotation is permitted in the leg. In fact, the fibula, which is a long slender bone, running nearly parallel with the tibia, looks like a mere appendage or rudiment, and serves only for the attachment of muscles. The upper end of the tibia is broad, and has two shallow excavations, in which the condyles of the femur are received. Upon the front of the knee-joint we find a small separate bone, the *patella* or knee-pan: the purpose of this is, to change the direction of the tendons that come down from the front of the thigh, to be attached to the tibia; in such a manner as to enable them to act more advantageously, upon the principle formerly stated (§ 398). In the elbow-joint, this change was not required; since the ulna projects sufficiently far backward to afford advantageous attachment to the tendon of the extensor muscle. The very powerful muscles which tend to straighten the knee-joint, arise from the front of the pelvis, and from the femur itself; and they form the fleshy mass of the front of the thigh. On the other hand, those which bend the knee arise from the lower border of the pelvis, and from the back of the thigh-bone, and pass downward to be inserted into the sides of the tibia and fibula a little below the knee, their tendons forming the two strong cords known as the *hamstrings.* The articulating surface at the lower extremity of the leg, which enters into the ankle-joint, is principally formed by the tibia; but its outer border is formed by the fibula, which there makes a considerable projection, that can be felt through the skin.

437. The *foot* is composed, like the hand, of three distinct portions, which are called the *tarsus, metatarsus,* and *toes.* There are seven bones in the tarsus, all of which are larger than those of the carpus, and some of them of considerable size. The articulation with the leg is formed by one of these only, the *astragalus,* which projects above the rest, and is imbedded between the projecting extremity of the tibia (which forms the inner boundary of the ankle-joint) and that of the fibula. The astragalus rests on the *os calcis,* or bone of the heel, which projects considerably backward, and is connected in front with the other bones of the tarsus. In front of the tarsus, we find the metatarsus, composed of five long bones, which, in Man, are all attached to each other, but of which one is separate in the Quadrumana, in order to give freer play to the great-toe, the action of which resembles that of the thumb. The toes, like the fingers, are composed of three phalanges (with the exception of the great-toe, which has only two); these are, in Man, much shorter than those of the hand, and are evidently not adapted for prehension; but, in many of the Quadrumana, their length is nearly equal to that of the fingers, and the great-toe is as opposable as the thumb. The foot is far from being thus converted, however, into a perfect hand; but it becomes a very useful instrument for clasping the small branches and twigs of the trees, among which these animals live. The foot of Man is distinguished from theirs, by its power of being planted *flat* upon the ground, and thus of affording a firm basis of support. Even the Chimpanzee and the Orang, when they attempt to walk erect, rest upon the *side* of the foot; and the absence of a projecting *heel* causes them to be very deficient in the power of keeping the leg upright upon it; for it is to this projection that the strong muscles of the calf of the leg are fixed, by which the heel is drawn upward, or the leg drawn back upon it. Other muscles at the side and back of the leg, the direction of whose tendons is changed by a sort of pulley at the ankle-joint, aided by the muscles of the foot itself, serve to bend the toes—an action which gives great assistance in walking, running, leaping, &c.; and they are straightened by an extensor muscle, which lies on the front of the leg, and of which the tendon runs under an *annular ligament* that encircles the ankle, and is then divided and spread out to the toes, over the upper surface of the foot. The great-toe is a very important instrument in the act of walking, since much of the spring forward is given by the bending of its phalanges; and it is provided with two flexor muscles of its own.

438. On the internal side of the foot, the bones of the tarsus and metatarsus form a kind of vault or arch, which serves to lodge and protect the vessels and nerves that descend from the leg towards the toes. When this arrangement is not perfect (as sometimes happens), so that the foot is too flat, the nerves are compressed by the weight of the body, and the act of walking cannot be continued for a long time without pain. This arch further serves the important purpose of deadening the shock that would otherwise be experienced every time that the foot is put to the ground; for, by the elasticity of the ligaments which hold together the bones that compose it, a sort of *spring* is formed, which yields for a moment to the shock, and then recovers itself. We feel the difference which this makes, when we jump from a height upon our heels; the *jar* is then propagated directly upward from the heel to the leg, thence to the thigh, and thence to the spinal column; and if it were not for the peculiar manner in which this is constructed (§ 420), a severe shock of this kind might produce fatal effects by *concussion* (or shaking) of the brain. In animals which walk upon four extremities, the difference of direction in which the legs are connected with the spine, prevents a jar from being propagated along the latter, to a similar degree; but in those which are destined to obtain their food by sudden and extensive leaps, such as the animals of the Cat tribe (the Lion, Tiger, &c.), we find an arrangement of the bones of the foot well adapted to diminish the shock produced by the sudden descent of the body upon the ground.

OF THE ATTITUDES OF THE BODY, AND THE VARIOUS KINDS OF LOCOMOTION.

439. A small number of vertebrated animals—Serpents, for instance—bear habitually on the whole length of their bodies, which rest entirely on the ground; and their only movements are effected by undulations of the spinal column. But the rest are supported upon their extremities; and we give the name of *standing* to that position in which the animal rests, supported by its limbs, upon the ground or any firm horizontal basis. In maintaining this position, the *extensor* muscles, by which the joints are straightened, must be in continual action, since the limbs would otherwise bend beneath the weight of

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§ 435. Describe the *femur* and its muscles, and the manner in which it is joined to the pelvis. 436. Describe the bones of the leg, their relative situations and uses.—What is the situation and the use of the patella?—Why is not a patella required at the elbow?—Describe the situation and insertion of the muscles which move the leg. 437. Into what portions is the foot divided?—How is the foot articulated with the leg?—What is said of the *os calcis?*—Of the metatarsus?—Of the toes?—How does the foot of Man differ from that of the Quadrumanous animals?—Describe the manner in which the muscles act, in bending the foot?—Refer to plate 12.

§ 438. How are the bones of the tarsus and metatarsus arranged?—Describe the arch of the foot, and the advantages of its peculiar construction. 439. What muscles are in action while in the standing posture?—Why is long-continued standing more fatiguing than walking?

the body. Now, as the sense of fatigue in a set of muscles depends, in great degree, upon the length of time during which they have been in action, the maintenance of the standing posture for a long period is, in most animals, more fatiguing than walking; since, in the latter exercise, the action of the flexors alternates with that of the extensors.

440. But this condition is not the only one essential to steadiness in the standing posture; for in order that the body may rest firmly upon the members, it must be in *equilibrium*. Equilibrium exists—or, in other words, a body remains at rest in its position—not only when it bears upon the whole of a broad surface, but also when it is so placed that the tendencies of its different parts to descend or gravitate towards the earth counterbalance each other. This is the case when its *centre of gravity* is supported; that is, when a line drawn perpendicularly from it falls within the base. In order, then, that an animal may rest in equilibrium on its legs, it is necessary that the vertical line from its centre of gravity (or *line of direction*) should fall within the space which its feet cover and inclose between them; and the wider this space, in proportion to the height of the centre of gravity, the more stable will the equilibrium be, since the body may be more displaced without being upset. Thus, in fig. 66, the table *a* must be upset; because the line of direction, *e*, from the centre of gravity, *c*, falls outside the base of support, *d;* while the table *b*, although equally inclined, will not be upset, but will return to its proper place; because the line of direction, *e*, from *its* centre of gravity, *c*, falls within its base, *d*. Hence, an animal which is supported upon four legs, will stand much more firmly than one which rests on two only; since its real base is the whole space included between its four points of support. And again, an animal is more firm when standing upon two legs, than when resting upon one only.

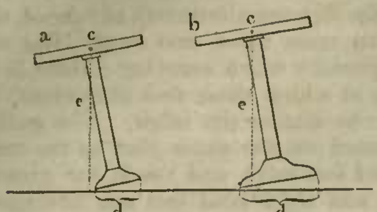

Fig. 66.

441. Moreover, when an animal rests upon four legs, the extent of its base is but little influenced by the size of the feet; and thus, to render them broad, would be to increase their weight, without adding much to their use as supports. This is easily understood by comparing a quadruped to a four-legged table; if the legs are sufficiently strong to support the weight that rests upon them, it matters little in regard to the steadiness of the table, whether they bear upon the ground by mere points, or by flat surfaces; since it is the large surface that would be inclosed by lines joining them, which constitutes the real base. Hence we find that, in most quadrupeds, the limbs only touch the ground by slightly-dilated extremities; and the number of fingers is reduced more and more, without diminishing their effect as instruments of locomotion. Thus in the Ruminant animals, as the Deer, the number of toes is reduced to two in each foot, as seen in fig. 67, where *t* represents the tibia; *ta*, the bones of the tarsus; *c*, the bone of the metatarsus, termed the *canon* (in which the trace of a division into two pieces can be seen); and *p, pi, pt*, the three phalanges of the toes, of which the last is enveloped in the hoof, which is nothing else than a large *nail* inclosing the whole extremity of the toe. In the Horse, this consolidation is carried still further than in the Ruminantia; for it has only one toe in each foot; but we see the rudiments of an additional bone in the metatarsus (*b*, fig. 68), which is commonly termed *splint*-bone.

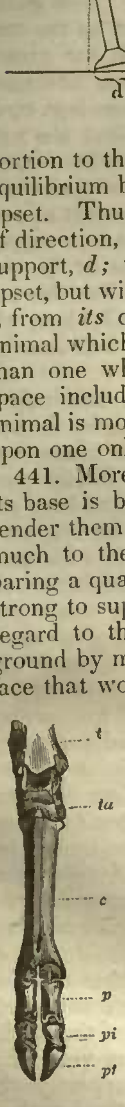

Fig. 67.

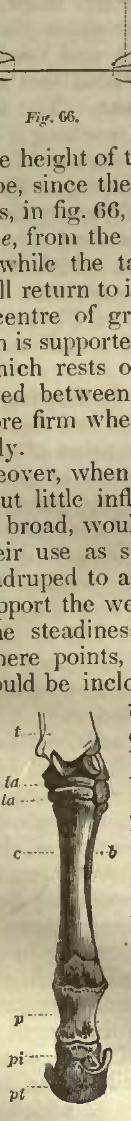

Fig. 68.

442. But when an animal is supported upon two feet only, whatever may be their degree of separation from each other, the base of support cannot have sufficient extent, unless the extremities touch the ground by a considerable surface. This is the case with the foot of Man, and still more with that of many Birds which habitually stand upon one leg. In order that an animal may hold itself in equilibrium upon a single limb, it is necessary that the foot should be placed vertically beneath the centre of gravity of the body, and that its muscles should be so arranged as to permit it to keep this limb inflexible and immovable. Man can accomplish this; for the centre of gravity of his body is about the middle of the pelvis; and to place this vertically over the foot, it is sufficient for him to bend himself a little from the side which is not supported. But the greater number of Quadrupeds are destitute of the power of doing this; and a large part of them cannot even raise themselves on their hind legs, on account of the direction of these members relatively to the trunk; or, if they can do so for an instant, they cannot maintain themselves in this position. The reason of this is very simple. The base of support, on account of the smallness of the feet, is very narrow, and the centre of gravity of the body is placed nearer the front, towards the chest; hence the body must be entirely changed in its position, by a violent and not sustainable action of the muscles which connect with the hind legs; and, when thus reared up, it cannot rest with firmness, on account of the narrowness of the base.

443. There are some Quadrupeds, however, which are able to raise themselves occasionally into this position; this is the case, not only with the Quadrumana, but also with the Bear, Squirrel, and other animals whose habits require them to ascend and live among trees; as well as in the Kangaroo, and animals constructed upon the same plan, whose peculiar organization will be presently considered. In maintaining the upright position, the muscles of the back part of the neck are kept in a contracted state, to retain the head in equilibrium on the vertebral column; and the extensor muscles of that column must also be kept in action, to prevent it from bending forward under the weight of the head, upper extremities, and viscera of the trunk. The whole weight of the upper part of the body is thus transmitted to the sacrum, and thence to the other bones of the pelvis, by which it is brought to bear on the femur. If left to themselves, the thigh bones would bend beneath the pelvis, and the trunk would fall forward; but the contraction of their extensor muscles keeps them firm. In the same manner, the extensor muscles of the knee and ankle keep these joints from yielding beneath the weight of the body; and it is thus at last transmitted to the soil. The *sitting* posture is less fatiguing than the standing position, because the weight of the body is then directly transmitted from the pelvis to the base of support, so that it is not requisite for the extensor muscles of the lower limbs to keep up a sustained action. But the *lying* posture is that of the most complete rest; because the weight of every part of the body is at once transmitted to the surface on which it bears; and no muscular movement is requisite to keep it in its position.

444. This difference in muscular effort is the cause of a well-marked variation in the pulse, according to the position in which the body is at the time. From a considerable number of observations, it has been found that the average pulse of an adult man is about eighty-one, when standing; seventy-one, when sitting; and sixty-six, when lying: so that the difference between standing and sitting was ten beats, or one-eighth of the whole; while the difference between sitting and lying was five beats, or one-thirteenth of the whole. In the female, the pulse is quicker, in each position, by from ten to fourteen beats per minute; but the differences occasioned by position are nearly the same. It will be observed that the difference between standing and sitting is greater than that between sitting and lying; and this closely corresponds with the relative amounts of muscular exertion required in these positions respectively. At the moment when the posture is changed, the pulse is considerably quickened, in consequence of the muscular effort required for the purpose, which acts especially on the veins, and forces the blood more rapidly back to the heart; but this increase in rapidity is temporary only.

445. The progressive movements by which the bodies of Man and other animals are made to change their places, are accomplished by means of the alternate contractions and extensions of those limbs which we have hitherto considered only as supporting them in a rigid position. It is easy to see that, when a joint is straightened after being bent, the two ends of the levers which form it must be separated from each other, and that motion must thus be given to the

§ 440. Explain fig. 66, and show how equilibrium is maintained; and why an animal rests more firmly on four legs than on two. 441. Why need not the feet of Quadrupeds be made broad?—Describe the construction of the foot of a deer, and of a horse. 442. Why must the foot of a two-legged animal be broad?—Why cannot most Quadrupeds maintain themselves on their hind-legs?

§ 443. Describe the mode in which the upright position is maintained.—Why is the sitting posture less fatiguing than the standing position?—Why is the lying position the easiest of all? 444. Describe the variations of the pulse caused by this difference in muscular effort.—Why is the pulse quickened at the moment of changing the posture? 445. How are the progressive movements of animals accomplished?—Explain the action of the bone-levers in progression.—Describe the action of the feet and legs in walking.

parts against which one or both of them bear. Now, in the ordinary movements of progression, one of these levers bears against the ground, which is immovable; and the whole motion produced by straightening the joint must, consequently, be communicated to the body. In the ordinary act of *walking*, one of the feet is planted in front, while the other is extended or carried backward beneath the leg, by the action of the muscles of the calf, aided by those of the toes. Its length is thus increased; and as it bears upon the resisting soil, this elongation acts through the thigh upon the pelvis, and thus carries forward the whole body. At the same time, the pelvis makes a slight turn upon the femur of the other side, on which it is resting; and the limb, which was at first behind the other, is now drawn forward by a flexion of its joints, and is planted on the ground in front of the other, so as to serve for the support of the body in its turn; while the other, by extending itself, gives a fresh forward impulse to the body. Thus each limb is alternately made to support the whole weight of the body, just as it would do in standing on one leg; and, at the same time, the other is engaged in urging it forward. Hence, the centre of gravity must vibrate a little from side to side, in the act of walking, so that it may be brought alternately over each foot; and this movement from side to side is the more obvious, in proportion as the pelvis is wider, and the limbs more separated from each other. Hence it is more seen in women than in men, on account of the greater proportional breadth of the hips in the former.

446. In all the higher animals, as in Man, there are members which serve for locomotion; but the nature of their movements varies greatly, and there is a corresponding difference in the structure of the instruments by which they are performed. The manner in which the Creator has made the same organs answer a variety of different purposes, in accordance with the habits of animals to which they belong, is a most interesting object of study; for we see the most varied results attained, without the least departure from the general plan which has been adopted in the construction of the various species of the same group; and this solely by slight changes in the forms and proportions of some of the instruments, the union of which makes up the entire body. The organs of locomotion in the Mammalia furnish us with obvious examples of this principle. This class includes not only the Quadrupeds which run or bound along the surface of the ground, but animals which are destined, like Fishes, to live solely in water; others which, like Amphibia, sometimes swim through that element, and sometimes inhabit the land; others, again, which possess wings that enable them to fly through the air like Birds; and others, which only employ their anterior members for grasping or feeling; yet, in all these animals, these organs are constructed of the same parts. In the paddles of a Seal, the wing of a Bat, and the fore-paw of a Squirrel, or a Mole, we find the same bones as in the arm of Man; and even in the fore-legs of the Ruminant Quadrupeds, and in those of the *Solidungula*, or single-toed animals (such as the Horse), we can usually perceive traces of the existence of three or four toes, whose bones are more or less completely united.

447. From what has already been stated, as to the influence of the length of the levers on the quickness of the movement of the extremities, it is easy to see that animals which have the most rapid progression must necessarily have long members; since—the quickness with which the extensor muscles act remaining the same—the change of place in the free extremity of the lever will be greater, in proportion as that extremity is more distant from the point of insertion of the muscles that move it, and from the fulcrum on which the lever works. But in proportion to the elongation of this arm of the lever must be the increase in the power of the muscles that move it, in order to overcome the same resistance; according to the general principle, that what is gained in velocity is lost in power. Hence, in order to endow an animal with great agility, it is only necessary to lengthen its limbs, and to render the muscles capable of exerting a proportional power.

448. We have seen that in *walking*, the body is sustained upon one limb (in *quadrupeds*, upon one pair of limbs), while it is pushed onward by the other; so that it ceases to bear upon the ground. In *running*, however, the body of Man momentarily quits its support at intervals; the foot in advance not being planted on the ground, at the time that the hinder one quits it. In this action, the Ostrich and its allies probably surpass all other animals; as they can outstrip the fleetest horse at full gallop, or the swiftest gray-hound at its greatest speed. The *amble* of Quadrupeds is a pace which resembles the walk or run of Bipeds, the two legs on one side being moved together, while the body rests upon the other. This pace is peculiar to the Giraffe, and to horses which have been trained to execute it. The *trot*, however, is a step of a different and much more secure nature. The fore-foot of one side is raised and advanced with the hind-foot on the other side; and, when these are set down, the other fore and hind feet are raised and advanced together. Now, if we consider the fore-feet of a horse as constituting the four angles of a parallelogram, it is easy to see that the base of support, when the feet are thus raised, will be one of the diagonals; and as the feet are alternately advanced, the weight will alternately be thrown upon these two lines. But the centre of gravity in the horse, especially when carrying a rider, is in a point almost exactly above that at which these two lines cross; so that it is always supported either by one or the other. The *gallop* of greatest speed is a *run* performed on the same plan as the trot; that is, the right fore and left hind feet leave and reach the ground together, and then the left fore and right hind feet are advanced. The *canter* is a kind of step altogether different. The four legs strike the ground successively—the left hind-foot reaching it first, the right hind-foot second, the left fore-foot third, and the right fore-foot fourth. The celebrated race-horse Eclipse, when galloping at liberty, and with his greatest speed, passed over the space of twenty-five feet at each stride or leap; this he repeated two and one-third times in a second, so as to pass over fifty-eight feet in that time, which was at the rate of nearly four miles in six minutes and two seconds. But this performance was completely surpassed by that of Flying Childers, who was computed to have passed over eighty-two and one-half feet in a second, or nearly a mile in a minute.

Fig. 69.—KANGAROOS.

449. In *leaping*, the body is projected into the air by the sudden extension of the joints, especially those of the hinder parts of the body, which had been previously bent; and having traversed a greater or less distance, the body comes again to the ground, and may be again projected. This is a kind of motion usually practised by many animals whose structure is expressly adapted to it. Thus, among Quadrupeds, we find several in which the hind legs are enormously elongated, for the purpose of giving greater quickness to the motion of the body; and their muscles are developed to an extraordinary degree, in order to supply the necessary force. This is the case among animals such as the Hare, Rabbit, Squirrel, &c.; but particularly in the Jerboa or Jumping Rat, and in the Kangaroo and its allies. In these animals, the fore-feet, which are little used for progression, are comparatively small; and, in the last, they are less than half the length of the hinder limbs. The feet, as well as the legs of the Kangaroo, are very long, in order to afford (in conjunction with the tail) a firm support to the animal when preparing to leap. Quadrupeds, in which the length of the posterior extremities greatly predominates over that of the anterior, are observed to descend hills with difficulty at a rapid pace, since the forward inclination of their bodies places them in continual danger of upsetting; they therefore take a zig-zag course. In ascending a hill, however, their progression is greatly favored by the length of their posterior extremities. The Rabbit, when moving slowly, advances the fore-feet two or three steps alternately, the posterior limbs remaining inactive; and the body having been lengthened by these means, the posterior legs are suddenly extended and drawn forward simultaneously: thus the rabbit walks with the fore, and leaps with the hind pair of legs. The Frog moves in a very similar manner.

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§ 446. What is said of the manner in which the same organs are made to answer a variety of purposes in different animals?—What examples of this principle are given? 447. What two conditions are necessary to endow an animal with great agility?—Explain the reasons why a swift animal must have long legs, and corresponding powerful muscles. 448. Describe the difference between the action of the limbs in walking and in running.—What is said of the running of the Ostrich?—Describe the amble, the trot, the gallop, the canter.—What examples are given of the rapidity of the gallop in Horses?

§ 449. Explain the means by which the act of *leaping* is effected.—Describe the construction of the limbs of the Hare, Squirrel, Kangaroo, &c., as adapted to leaping.—Why do such animals descend a hill with difficulty, and ascend it with ease?—Describe the gait of the Rabbit.

PLATE XII.

ORGANS OF MOTION.—THE MUSCLES.

LATERAL VIEW OF THE PRINCIPAL MUSCLES OF THE HUMAN BODY.

MUSCLES OF THE HEAD AND NECK.

1, The occipito-frontalis muscle, which elevates the eyebrows, and wrinkles the forehead, expressing astonishment or attention. 2, The orbicularis palpebrarum, which closes the eyelids. 3, Triangularis nasi, which compresses the nostrils. 4, The levator labii superioris, which raises the upper lip and expands the nostrils, expressing disdain. 5, Zygomaticus major. 6, Zygomaticus minor: These muscles raise the upper lip and draw it outward. 7, Orbicularis oris.—Only half this muscle is seen on the plate. It extends completely around the mouth, which its action is to close. It also assists the lips in whistling, blowing and sucking. 8, The buccinator, or trumpeter's muscle.—It elongates the mouth transversely, and is greatly used in blowing wind-instruments. 9, Depressor labii inferioris, which draws down the under lip, expressing chagrin, disgust. 10, Depressor anguli oris, which depresses the angle of the lips. 11, The masseter.—This powerful muscle is the essential agent in mastication. It raises the lower-jaw, and brings its teeth strongly against those of the upper-jaw. 12, Omo-hyoideus, extending from the edge of the scapula to the hyoid-bone, which it depresses. 13, Sterno-hyoideus, a depressor of the larynx. 14, The digastricus, an elevator of the larynx and a depressor of the lower jaw. 15, The Sterno-cleido-mastoideus, extending from the temporal-bone to the sternum and clavicle.—When one of these contracts, it draws the head to its own side; when both contract, the head is carried forward. 16, The upper portion of the trapezius.—(*See* Plate XIII.) 17, 18, Scalenus posticus and anticus, which elevate the ribs and assist in respiration.

MUSCLES OF THE TRUNK.

19, The pectoralis major, a large muscle, attached to the clavicle, sternum and ribs, and to the humerus. It draws forward the shoulder and also elevates the ribs, acting as a muscle of inspiration. 20, The serratus magnus, a powerful muscle, lying beneath the pectoral muscle.—It is divided into slips or digitations which extend from the ribs to the scapula. It is a muscle of inspiration, the contraction of its slips tending to separate the ribs and thus dilate the chest. 21, 21, &c. External intercostal muscles, which elevate the ribs. 22, The transversalis abdominis. This muscle draws the front of the abdomen inward, thereby pushing up its contents against the diaphragm, in the act of expiration. 23, Rectus abdominis, which draws the chest forward toward the pelvis, and assists in straightening the trunk when it has been thrown backward.

MUSCLES OF THE SUPERIOR EXTREMITIES.

24, The deltoid muscle. This thick and powerful muscle is attached to the scapula and to the humerus. Ordinarily it elevates the arm; but when the body is raised by the arms, as in climbing, it draws up the trunk. 25, The biceps brachialis.—This is the large muscle whose projection is felt in front of the arm. It is a flexor of the fore-arm. (§ 405). 26, 26, 26, Portions of the triceps brachialis.—(*See* Pl. XIII). 27, The pronator teres.—This muscle, being attached to the radius, and having its fixed insertion on the humerus, rolls the radius inward, and thus turns the palm of the hand downward. 28, The supinator longus.—This muscle acts as an antagonist to the last, and turns the hand upward. 29, The flexor carpi radialis. 30, The palmaris longus. 31, Flexor carpi ulnaris.—These three muscles are flexors of the wrist upon the fore-arm. Their white and slender tendons are attached to the carpal and metacarpal bones. 32, Tendons of the flexor sublimis digitorum, which bend the second range of the finger-bones upon the first. 33, Extensor carpi radialis longior.—This muscle extends the wrist upon the fore-arm. 34, Extensor communis digitorum.—(*See* Pl. XIII.) 35, Lower portion of the abductor pollicis longus. 36, Lower portion of the extensor pollicis brevis.—These two muscles draw the thumb outward, and bend it on the carpus. 37, Extensor carpi ulnaris.—(*See* Pl. XIII.)

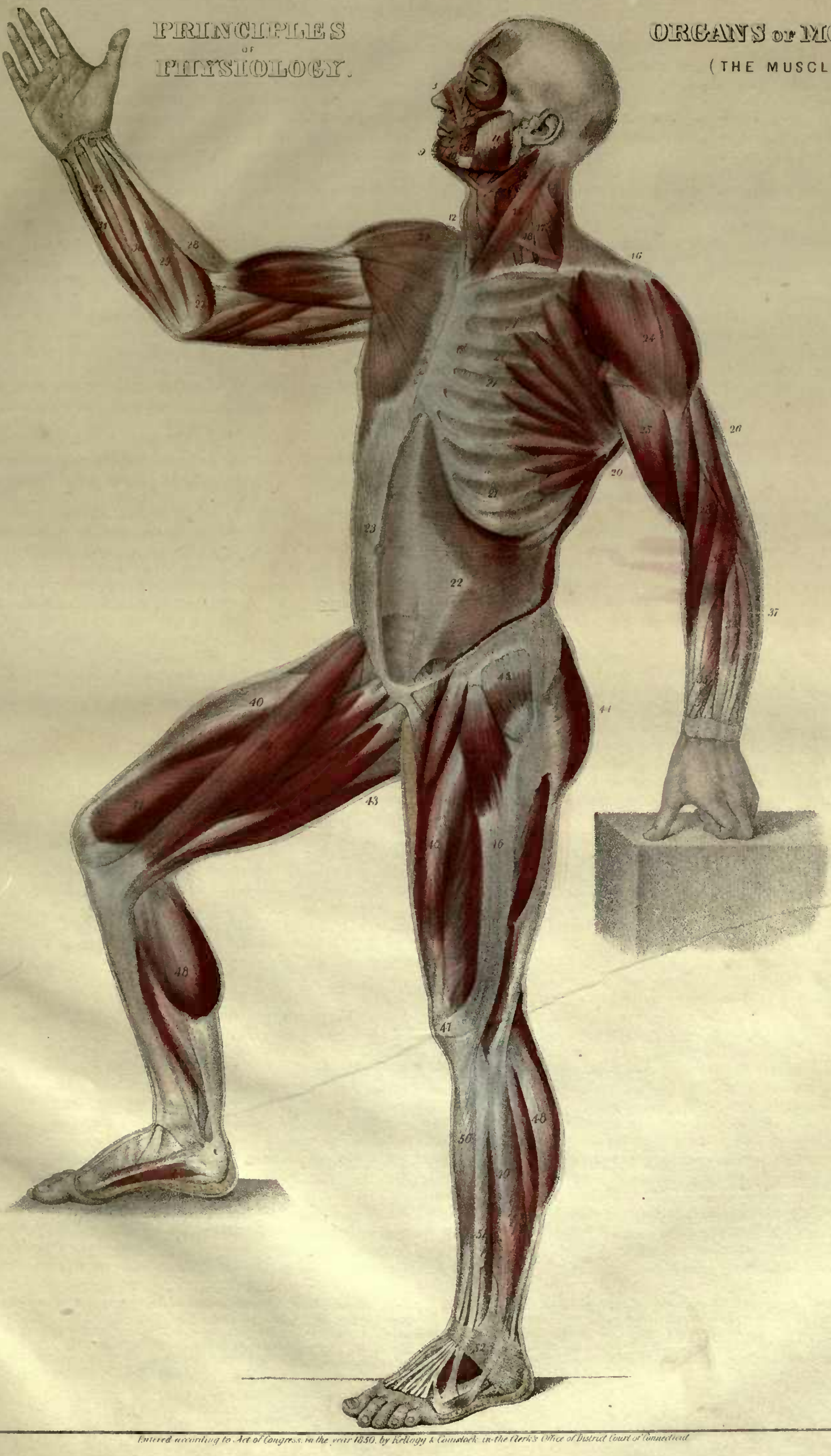
MUSCLES OF THE INFERIOR EXTREMITIES.

38, The rectus internus.—This muscle is a flexor of the leg. 39, The sartorius or tailor's muscle, the longest muscle in the body.—By its action the legs are bent inward, so as to cross each other. 40, The rectus femoris. 41, The vastus internus. 42, The vastus externus.—These three muscles extend the leg upon the thigh. 43, Portion of the adductor magnus.—This muscle draws backward the thigh at the hip. 44, A portion of the gluteus maximus.—(*See* Pl. XIII.) 45, The gluteus medius. 46, A tendinous expansion called the fascia-lata, forming part of the femoral aponeurosis. 47, The tendon of the vastus femoris, which contains the patella. 48, The triceps suræ, or extensor of the foot, composed of three large fasciculi.—(*See* Pl. XIII.) 49, The peroneus longus; its tendon passes behind and beneath the outer ankle, in a pulley-like groove, and is inserted into the first metatarsal-bone. By its contraction, this muscle extends and rotates the foot. 50, The tibialis anticus.—This muscle is attached by its tendon to a bone of the instep, and bends the foot upward. 51, The extensor digitorum communis.—Its four tendons are seen proceeding under the annular ligament of the tarsus, and diverging to the four smaller toes. This muscle extends the joints of the toes, and bends the foot upon the leg. 52, Annular ligament of the tarsus. 53, Adductor pollicis pedis.—(*See* Pl. XIII.)

PRINCIPLES OF PHYSIOLOGY.

ORGANS OF MOTION.

(THE MUSCLES.)



Lith of Kellogg

Entered according to Act of Congress, in the year 1850, by Kellogg & Comstock in the Clerk's Office of District Court of Connecticut

Hartford Conn.

450. *Swimming* and *Flying* are movements which have much resemblance to each other; both being executed in a fluid medium, which, to a certain extent, buoys up the body—which offers resistance to its progress, and which also offers something resembling a fixed point, on which the members may act to propel it. The chief differences between them depend upon the nature of the medium—this being liquid in the one case, and aëriform or gaseous in the other. The liquid medium affords more support to the body, and a firmer surface for the action of its propelling organs; but, at the same time, it offers more resistance to its progress. The movement of a body through the atmosphere, as in flight, requires a considerable expenditure of power to keep it up; and the yielding nature of the element prevents the propelling organs from acting against a firm surface; but the onward movement, in consequence of the slight resistance, is easily accomplished.

451. When the feet of a quadruped are to serve both as walking and swimming organs, the end is accomplished by the spreading of the fingers, and their union by means of a fold of skin, which is stretched over them; as the web of a swimming Bird is stretched over its toes, so as to make an oar or paddle of sufficiently wide surface. This is the case, for example, in the Beaver and the Otter. When the members are intended exclusively for swimming, however, they undergo more considerable modifications in structure. The parts corresponding with the arm and fore-arm are very short, and the movements of the hand are thus limited, but they can be accomplished with all the more force. But the bones of the hand are large and spread asunder, and are inclosed in a firm integument, which may even cover their extremities. Sometimes the number and arrangement of these bones are precisely the same as in the hand of Man; this we see in the seal, where their extremities are furnished with separate claws that project beyond the integument. Sometimes the number of phalanges in the fingers is considerably increased, as in the Whale; and, in other instances, the fingers are replaced by a multitude of small rods of bone, inclosed within a continuous skin, such as we see in the fins of Fishes (see plate 10, fig. 4).

452. In the Whale and its allies, the posterior extremities are almost entirely wanting, and the tail is greatly prolonged, and expanded at its extremity. This expansion, however, (which is in the *horizontal* direction) is not supported by bones, except in its centre; but it consists internally of cartilages and tendons, which last are prolonged from a set of very powerful muscles that are attached to the spine, and give to this organ an enormous force and great variety of motion. The texture of the portion of it by which the blow is usually given, is such that it can hardly be injured; it is so tough that it cannot be torn, and so free from feeling, that a stroke of it against a hard substance gives no pain to the animal. If it strikes a boat across the middle with the edge, the boat is cut asunder as clean and suddenly as if by one stroke of a giant axe; whereas, if it strikes with the flat surface, the boat is driven to the depth of many fathoms with the swiftness of an arrow. Hence this tail is a most efficient instrument for the propulsion of the bulky body of the Whale through the water; and it is, in fact, its principal organ of locomotion. The paddles formed by the fore-feet are placed near the centre of gravity of the whole mass; and thus can readily exert their peculiar action, which is that of changing the direction of the movement, and especially of raising and lowering the body.

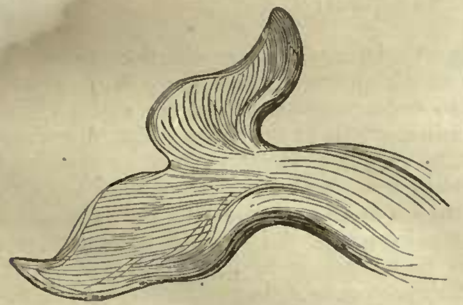


Fig. 70.—Tail-Fin of Whale.

453. The propulsion of the body by the stroke of the tail in Whales and Fishes, is effected precisely in the same manner as the urging forward a boat through the water, when accomplished by the motion of an oar at the stern from side to side—in the mode commonly termed *sculling*. The expansion of the Whale's tail-fin being horizontal, its stroke is vertical, and may thus readily bring the animal to the surface of the water for occasional respiration, as well as propel it forward; but that of the Fish's body and tail being vertical, its stroke is horizontal, and its action will simply be, to urge the body through the water. The power of ascending and descending, as well as of changing the direction of the motion, is principally due to the side-fins, which represent the arms and legs. The direction of the surface and stroke of these side-fins varies in different species. In the Cod, Halibut, and others, their action appears to be principally directed towards keeping the body in its right position in the water; since, without such an action, the body would be liable to turn over, in consequence of the position of its centre of gravity.

454. True *wings* or instruments of propulsion as well as of support in the air, are universally formed by some modification of the anterior extremities, which renders them unfit to be used as instruments of progression on the ground; but the nature of this modification varies considerably. The general form of the skeleton of Birds is shown in plate 10, fig. 3, which represents that of the Vulture. The head is supported upon a very flexible neck, of which the vertebræ are often very numerous (*v c*). The vertebræ of the back and loins, however, are usually few in number, and are connected together very firmly, so as to form a nearly flexible column; and this again is closely united to the sacrum, *v s*. The vertebræ of the tail, *v q*, are also small in number, and possess little motion. The ribs are very strongly connected to each other and to the vertebræ, and are united to the breast-bone, *s t*, by bony instead of cartilaginous prolongations. Thus the whole bony apparatus of the trunk is very strongly knit together; and the purpose of this is evidently to give as firm an attachment as possible to the muscles which move the wings. The greatest power which these organs require, is in the downward direction; in order that, by their stroke, they may raise the bird in the air, or keep it from falling. Accordingly, we find that the great mass of flesh or muscle that puts them in action, lies on the breast-bone, the centre of which, *st*, is raised into a high keel or ridge for its attachment. On the other hand, the muscles that raise the limb, and draw it backward, which are attached to the blade-bone of Mammalia, and are usually strong in them, are comparatively weak in birds, whose scapula (forming part of the *side-bone*) is very narrow. Moreover, in order to keep the wings properly apart, there is a very strong clavicle or collar-bone, *cl*, in birds; and this, though it exists in Man, and in Mammalia that use their fore-arm for other purposes than support and motion, is deficient in the greater part of those that employ it only as a leg.

455. We notice further the *humerus* or arm-bone, constituting the first bone of the pinion; the two bones of the *fore-arm;* the bones of the wrist, which are here scarcely developed; and the bones of the fingers, each joint of which shows indications of being made up of two or three separate bones united together. In no Bird are these bones ever separated into distinct fingers; since they are never applied to any other purpose than that of supporting the wing-feathers. In the hinder extremity of the bird we find a thigh-bone (principally concealed in the figure by the bones of the wing), the two bones of the leg, which are commonly in part united; the shank or ankle bones, and the four separate toes, by the spread of which the body is firmly supported, though it rests only on two feet.

456. In the Bat, the plan on which the wings are constructed is very different. We have here no long stiff feathers, by the projection of which, from the wing itself, the surface may be increased to almost any extent; but the wing is formed by an expansion of soft and delicate skin, over a frame-work of bones, which must consequently be made to support it to its very edge. This is accomplished by the enormous extension of the bones of the hand, especially the metacarpal, which are here separate; and the membrane is farther sustained by the legs and tail. The thumb is not included in the wing, but serves as a hook by which the animal can suspend itself.

457. The wings of Insects have no analogy whatever with those of Vertebrata, except in regard to their use, and in being composed of an expanded surface of membrane, stretched upon a hard frame-

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§450. In what respects do the movements of swimming and flying resemble each other?—How do they differ from each other? 451. How are the feet of a Quadruped made to serve for both walking and swimming?—How are they constructed, when intended exclusively for swimming? 452. Describe the structure and action of the tail of the Whale? 453. Explain the mode in which the fin and tail of Fishes operate in producing motion?—What is the principal use of the side-fins?

§454. Refer to plate 10, fig 3, and point out and describe the bones of the Vulture.—Describe the action of the wings and of the muscles by which they are moved.—Describe the peculiar clavicle of birds, &c. 455. Describe and point out the bones of the wings, of the hinder extremities, &c. 456. Describe the wing of the Bat.—How is the membrane of its wing supported? 457. What is said of the construction and action of the wings of insects?

work. This frame-work is not composed, however, of solid pieces jointed together; but is merely an extension of the air-tubes and vessels within the body, which are strengthened by a continuation of its hard envelope. Their only action is a hinge-like movement at the point where they are united to the body; and this is accomplished, partly by the great velocity of the down-stroke compared with the up-stroke, which causes the resistance of the air to be much greater in the former than in the latter. But it is by the alteration in the surface of the wing, as it acts upon the air, that the chief difference is made. In Birds, the arrangement of the great feathers is such that they strike the air with their flat sides, but present only their edges in rising.* And in Insects, the expansion of the wings may be altered by the degree in which the air-tubes, that constitute the principal parts of their nerves or frame-work, are distended with air, by the pressure of the muscles contained in the body upon the air-sacs within.

459. The degree in which the wings act in raising the body, or in propelling it through the air, varies considerably in different animals, according to the way in which they are *set*. Thus, in Birds of Prey, which require a rapid horizontal motion, the surface of the wings is very oblique, so that they strike backward as well as downward, and thus impel the body forward while sustaining it in the air. Such birds find a difficulty in rising perpendicularly; and can, in fact, only do so by flying against the wind, which then acts upon the inclined surface of the wings just as it does upon that of a kite. On the other hand, the Lark, Quail, and such other birds as rise to great heights in a direction nearly vertical, have the wings so disposed as to strike almost directly downward. It has been estimated that a Swallow, when simply sustaining itself in the air, is obliged to use as much force to prevent its fall, as would raise its own weight to a height of about twenty-six feet in a second. Hence, we may form some idea of the enormous expenditure of force which must take place, when the body is not only supported, but raised and propelled through the air. The Eider-duck is said to fly ninety miles in an hour, and the Hawk one hundred and fifty. The Swallow and Swift pass nearly the whole of the long summer days upon the wing, in search of food for themselves and their helpless offspring; and the rapidity of their flight is such, that they can scarcely traverse less than seven or eight hundred miles in that time, although they go but a short distance from home. The flight of Insects is even more remarkable for its velocity in proportion to their size. Thus, a Swallow, which is one of the swiftest-flying of birds, has been seen to chase a Dragon-fly for some time without success; the insect always keeping about six feet in advance of the bird, and turning to one side and the other so instantaneously, that the Swallow, with all its powers of flight, and tact in chasing insects, was unable to capture it.

460. If the preceding estimate of the power expended by a bird in sustaining itself in the air be correct, it may be easily proved that it would be impossible for a man to sustain himself in the air, by means of his muscular strength alone, in any manner that he is capable of applying it. It is calculated that a man of ordinary strength can raise thirteen and one-quarter pounds to a height of three and one-quarter feet per second; and can continue this exertion for eight hours in the day. He will then exert a force capable of raising $(13\frac{1}{4}\times60\times60\times8)$ three hundred and eighty-one thousand six hundred pounds to a height of three and one-quarter feet; or one-eighth that amount, namely, forty-seven thousand seven hundred pounds, to the height of twenty-six feet, which, as we have seen, is that to which the bird would raise itself in one second, by the force it is obliged to exert, in order to sustain itself in the air. Now, if we suppose it possible that a man could by any means concentrate the whole muscular power required for such a day's labor into as short a period as the accomplishment of this object requires, we might find the time during which it would support him in the air, by simply dividing this amount by his weight, which we may take to be one hundred and fifty pounds. The quotient is three hundred and eighteen, which is the number of *seconds* during which the expenditure of a force that would raise forty-seven thousand seven hundred pounds to a height of twenty-six feet will keep his body supported in the air; and this is but little more than five minutes. There is no possible means, however, by which a man could thus concentrate the force of eight hours' labor into the short interval in which he would have to expend it, when supporting himself in the air; and by no combination of mechanical powers can force be *created;* as these only enable force to be more advantageously applied. Hence, the problem of human flight will never be solved, until some source of power shall be discovered far surpassing that which his muscular strength affords, and so portable in its nature as not materially to add to its weight.

461. The only other organs of locomotion which we have to consider, are those of *prehension*. The hand of Man is seldom employed to assist in his locomotion, except in swimming (where it serves the purpose of a fin), and in climbing; neither of which kinds of movement can be said to be natural to him. But the claspers of the Monkeys are most efficient instruments of locomotion; enabling them not only to grasp the branches of the trees which they climb to despoil them of their fruit, but also to catch hold of them at the end of a long leap. This they do with the most wonderful agility; as all who have seen Monkeys in circumstances at all like those of their natural habitations must have observed. There are many of the Monkey tribe, however, especially in the New World, whose hands are less efficient as instruments of prehension; and these are furnished with a *prehensile* tail; that is, a tail which can be coiled round the branch of a tree, and by which the animal can suspend itself. A similar tail is possessed by some of the Opossum tribe; and by the Chameleon among Reptiles.

Fig. 71.—THE CHIMPANZEE.

CHAPTER XIII.

THE VOICE.

462. IN all air-breathing Vertebrata, the production of sound depends upon the passage of air through a certain portion of the respiratory tubes, which is so constructed as to set the air in vibration. In Reptiles and Mammalia, it is at the point where the wind-pipe opens into the front of the pharynx, that this vibrating apparatus is situated. Few of the animals of the former class, however, can produce any other sound than a *hiss*, occasioned by the passage of air through the narrow chink by which the trachea communicates with the pharynx; but this sound, owing to the great capacity of their lungs, is often very much prolonged. In the Mammalia, on the other hand, there are few, if any, which have not some vocal sound; but the variety and expressiveness which can be given to it differ considerably in the several tribes of the class, being by far the greatest in Man. This sound is produced by the apparatus termed the *larynx*, which is situated beneath the base of the tongue, and in front of the pharynx. It is suspended, as it were, from the *hyoid-bone* (*h*, fig. 72) —a bone of a horse-shoe form, detached from the rest of the skeleton; from two projections (*l*), on the upper side of which several of the muscles of the tongue originate. The sides of the larynx are formed by two cartilages (*t*, fig. 72), which are termed the *thyroid* cartilages; where these meet on the middle line, a projection is formed, which is particularly prominent in Man, and has received the name of *Pomum Adami*, or Adam's Apple (*a*). The thyroid cartilages rest upon another, termed the *cricoid* (*c*); this has the form of a ring, much deeper behind than in front, and surmounts the trachea, with the upper ring of which its lower edge is connected by a membrane. Upon the upper surface of the back of the cricoid cartilage, where there is an open space left between the two thyroid cartilages, are

§ 459. How does the *setting* of the wings of a Hawk differ from that of those of a Quail, and why is this difference?—What is said of the force expended in flying, and of the rapidity of flight in birds and insects?—What illustration is given of the comparative swiftness of birds and insects? 460. How is it proved that it is impossible for a man to fly?—Give the calculation.

§ 461. What is said of the organs of prehension, as used for locomotion? 462. How are the sounds of Man, and of all air-breathing vertebrate animals, produced?—Describe the construction of the larynx.—Refer to figs. 72, 73, 74, and to plate 9.

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* What is called *feathering the oar*, in rowing, is a similar operation, performed with the same intention, and deriving its name from this resemblance.

PLATE XIII.

ORGANS OF MOTION.—THE MUSCLES.

POSTERIOR VIEW OF THE MUSCLES.

The right side of the figure displays the outer or superficial layer of muscles. On the left side, they are represented clothed with their fasciæ or aponeuroses, which form a tendinous membrane.

MUSCLES OF THE HEAD AND NECK.

1, The occipitalis.—This muscle draws the scalp backward and downward, giving the expressions of joy or surprise. 2, Muscles of the ear. 3, The masseter. 4, The sterno-cleido-mastoideus. 5, The splenius.—When the two splenii act together, they draw the head backward, elevating the chin; when one acts, it bends the head and neck to one side.

MUSCLES OF THE TRUNK.

6, The trapezius.—This muscle is attached to the spinous processes of the dorsal vertebræ and to the scapula. It carries the shoulder backward. 7, The latissimus dorsi.—*a, a,* Its tendinous or aponeurotic portion.—This broad muscle draws down the arm, or, if the arm be fixed, it draws the trunk towards the shoulder. 8, Part of the obliquus externus.—This muscle compresses and raises up the contents of the abdomen.

MUSCLES OF THE SUPERIOR EXTREMITIES.

9, Posterior portion of the deltoid muscle. 10, The infra-spinatus.—This muscle turns the shoulder outward, and assists in keeping the head of the humerus in its socket. 11, 11, 11, The three portions of the triceps extensor cubiti.—This muscle is fixed by its tendon to the olecranon process of the ulna, and by its contraction it extends the fore-arm (§ 402). 12, The extensor communis digitorum.—Its four tendons pass under the annular ligament, and go to the four fingers; so that it becomes an extensor of the whole hand, as well as of each of the phalanges. 13, The extensor proprius of the little-finger.—By means of this slender muscle, the little-finger can be separately extended. 14, The extensor carpi ulnaris.—This muscle extends the hand on the wrist. 15, Flexor carpi ulnaris. 16, Tendon of the long extensor of the thumb. *l,* Annular ligament of the carpus.

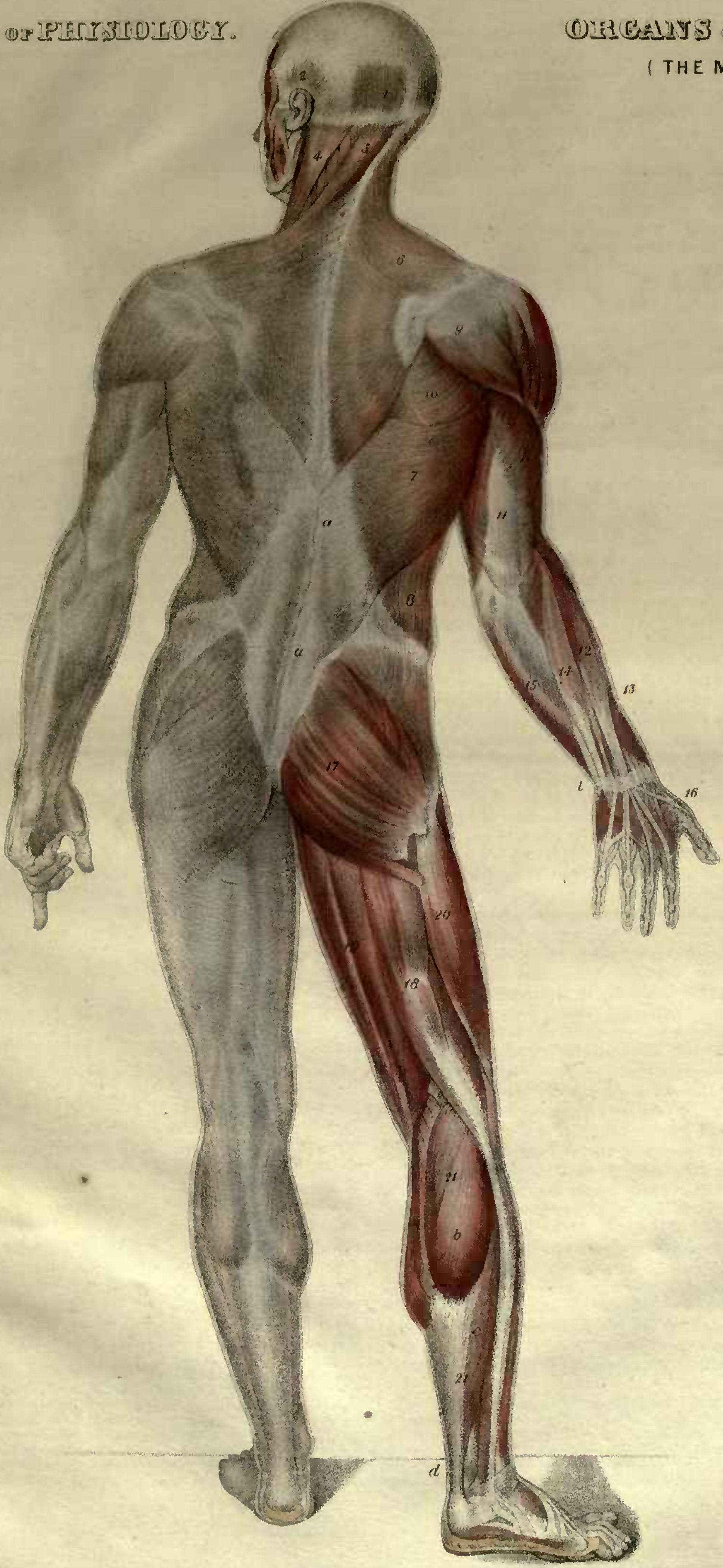
MUSCLES OF THE INFERIOR EXTREMITIES.

17, The gluteus maximus.—This large, thick muscle is of greater volume than any other in the body, and is the principal agent in preserving its equilibrium. It extends from the iliac bones to the femur, and acts as an extensor of the thigh. 18, The biceps femoris.—This strong muscle, extending from the pelvis to the tibia, bends the leg, and also extends the pelvis upon the leg, keeping it erect. 19, The semi-tendinosus.—This muscle bends the leg upon the thigh, turns the point of the foot downward and inward, and keeps the pelvis erect when standing. 20, The vastus externus. 21, 21, The triceps suræ, consisting of three portions—the gastrocnemii, *a, b,* and the soleus, *c;* it terminates in the strong tendon of Achilles, *d.* It forms the extensor muscle of the foot.

PRINCIPLES OF PHYSIOLOGY.

ORGANS OF MOTION.

(THE MUSCLES.)



Lith of Kellogg

Entered according to Act of Congress in the year 1850 by Kellogg & Comstock in the Clerk's Office of District Court of Connecticut

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mounted two small cartilaginous bodies, the *arytenoid* (*ar*, fig. 73). These are movable to a certain extent; and their position may be changed in various directions, by several muscles which act upon them.

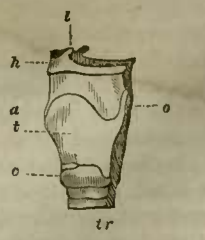

Fig. 72.—HUMAN LARYNX, VIEWED SIDEWAYS.—*h*, hyoid-bone; *l* point of origin of muscles of the tongue; *t*, thyroid cartilage; *a*. projection in front, commonly called Adam's Apple; *c*, cricoid cartilage; *tr*, trachea; *o*, posterior side of the larynx, in contact with the œsophagus.

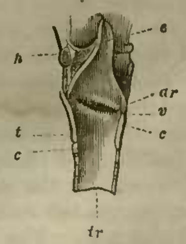

Fig. 73.—VERTICAL SECTION OF THE LARYNX.—*ar*, arytenoid cartilages; *v*, ventricle of the glottis; *e*, epiglottis. The other references as before.

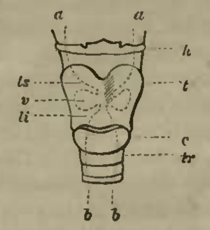

Fig. 74.—FRONT VIEW OF THE LARYNX.—The interior wall is marked by the lines *a*, *a*, *b*, *b*; *li*, inferior ligaments of the glottis, or vocal cords; *ls*, superior ligaments. The other references as before.

463. To these arytenoid cartilages are attached two ligaments, of elastic fibrous substance, which pass forward, to be attached to the front of the thyroid cartilage, where they meet in the same point. These are the instruments concerned in the production of sound, and also in the regulation of the aperture by which air passes into the trachea; and they are usually termed the *vocal cords* or *ligaments*. By the meeting of these ligaments in front, and their separation behind, the aperture has the form of a V; but it may be narrowed, by the drawing together of the arytenoid cartilages, until the two vocal ligaments touch each other along their whole length, and the aperture is completely closed. In this manner, the amount of air permitted to pass through the larynx is regulated, and a protection is afforded against the entrance of solid substances. An additional guard is afforded, by the doubling of the lining membrane in such a manner as to form a second pair of folds (*l, s*, fig. 74) above the preceding; and over the space between these (which is much wider than that between the vocal cords) there is a valve-like flap, the *epiglottis* (*e*, fig. 73), which is pushed down upon it in the act of swallowing, so as to prevent the entrance of solid or fluid particles into the space beneath, which is called the *glottis*. From the causes formerly mentioned (§ 135), such particles are occasionally drawn into the glottis; and they excite, by a *reflex* action, an involuntary and extremely violent cough, which tends to expel them again. Sometimes, however, solid bodies of no inconsiderable size find a lodgment in the wide spaces (*v*, fig. 74) between the upper and lower pair of ligaments, which are termed the *ventricles* of the larynx; and occasionally they pass through the opening between the vocal cords, which is termed the *rima glottidis*, or fissure of the glottis, into the windpipe.

464. In the ordinary acts of inspiration and expiration, the arytenoid cartilages are wide apart, so that the aperture is as large as possible; but for the production of vocal sounds, it is necessary that the aperture should be narrowed, and that the flat sides, rather than the edges, of the vocal ligaments, should be opposed to one another. This is accomplished by a peculiar movement of the arytenoid cartilages, occasioned by the contraction of certain muscles. When this is the case, the air, in passing through the larynx, sets these ligaments in vibration, in a manner very much resembling that in which the *reed* of a hautboy, or clarionet, or the tongue of an accordion, is set in vibration by the current of air that is made to pass beneath it. The rapidity of the vibrations, and consequently the *pitch* of the sound (§ 342), depends on the degree of *tension* or tightness of the vocal ligaments; and this is regulated by muscles which act upon the thyroid and arytenoid cartilages. If the thyroid cartilage be drawn forward, and the arytenoid cartilages backward, the two ends of the vocal cords will be further separated from each other, and they will consequently be tightened; by the contrary movements, they will be relaxed. The power which the will possesses, of determining, with the most perfect precision, the exact degree of tension which these ligaments shall receive, is extremely remarkable. Their average length in the male, in a state of repose, is estimated at about 73-100ths of an inch; while, in the state of greatest tension, it is about 93-100ths; the difference is, therefore, about 20-100ths, or 1-5th of an inch. In the female glottis, the average dimensions are about 51-100ths, and 63-100ths, respectively; so that the difference is only 12-100ths, or less than 1-8th of an inch. Now, the natural compass of the voice (or distance between its highest and lowest notes), in most persons who have cultivated the vocal organ, may be stated at about two octaves, or twenty-four semi-tones. Within each semi-tone, a singer of ordinary capability could produce at least ten distinct intervals; so that, for the total number of intervals, two hundred and forty is a very moderate estimate. There must, therefore, be at least two hundred and forty different states of tension of the vocal cords, every one of which can be at once determined by the will; and the whole variation in their length being not more than 1-5th of an inch, even in Man, the variation required to pass from one interval to another will not be more than 1-1200th of an inch; and yet this estimate is much below that which might be truly made, from the performance of a practised vocalist. It is said that the celebrated Madame Mara was able to sound one hundred different intervals between each tone. The compass of her voice was at least twenty tones; so that the total number of intervals was two thousand, all comprised within an extreme variation of 1-8th of an inch: hence it may be said that she was able to determine the contractions of her vocal muscles to the 1-16,000th of an inch.

465. It is on account of the greater length of the vocal cords, that the *pitch* of the voice is much lower in man than in woman; but this difference does not arise until the end of the period of childhood—the size of the larynx being about the same in the boy and girl, up to the age of fourteen or fifteen years, but then undergoing a rapid increase in the former, while it remains nearly stationary in the latter. Hence it is that boys, as well as girls and women, sing *treble;* while men sing *tenor*, which is about an octave lower than the treble; or *bass*, which is lower still. The cause of the variations of *timbre* or *quality* in different voices, is not certainly known; but it appears to be due, in part, to differences in the degree of flexibility and smoothness in the cartilages of the larynx. In women and children these cartilages are usually soft and flexible, and their voices clear and smooth; while in men, and in women whose voices have a masculine roughness, the cartilages are harder, and are sometimes almost completely ossified. The *loudness* of the voice depends, in part, upon the force with which the air is expelled from the lungs; but the variations, in this respect, which exist among different individuals, are due to the degree in which its resonance is increased by the vibration of the other parts of the larynx, and of the neighboring cavities. In the howling monkeys of South America, there are several pouches which open from the larynx, and are destined to increase the volume of tone that issues from it; one of these is excavated in the substance of the hyoid-bone itself, which is very greatly enlarged; and to this bony drum seems due the mournful plaintiveness which characterizes the tone of these animals. Although the largest of American monkeys, these howlers are inconsiderable in size; yet their voices are louder than the roaring of lions, being distinctly audible at the distance of two miles; and, when a number are congregated together, the effect is terrific.

466. In Birds, the situation of the vocal organ is very different. The trachea opens into the pharynx, as in reptiles, by a mere slit, the borders of which have no other movement than that of approaching one another, so as to close the aperture when necessary. But at the *lower* extremity of the trachea, just where it subdivides into the bronchial tubes, there is a sort of larynx or vocal organ, which is of very complex construction, especially in the singing-birds. The external surface of this larynx is represented in fig. 75; its muscles, *m, m*, being left in their places on one side, and removed on the other. At *t t*, is seen the trachea; at the lower extremity of which, *t'*, is a sort of bony drum, *l*, divided at its lower part by a partition of the same material (*o*, fig. 75), which is surmounted by a semi-lunar membrane (*c*, fig. 76). This drum communicates below with the two

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§ 463. Describe the vocal ligaments.—What is their use?—How are foreign bodies prevented from entering the glottis?—Point out all the parts of the vocal apparatus in the figures, and in plate 9. 464. How is the size of the aperture of the larynx varied, and for what purpose?—To what is the vibration of the vocal cords compared?—On what does the pitch of the voice depend, and how is it regulated?—What is said of the power of the will in determining the tension of the vocal cords?—How is this illustrated?—Give the calculations as to the variation of length of the vocal cord in musical intervals?—What remarkable instance of ability to sound intervals is given?

§ 465. What is the reason of the difference in pitch between male and female voices?—When does this difference arise, and what is said of it?—What is the reason of variations in quality of voice?—Upon what does the loudness of the voice depend?—What is said of the voice of the howling monkeys?—How is the loudness of their voice increased? 466 How does the larynx of the Bird differ from that of Man?—Refer to figures 75, 76, and explain the construction of the vocal organs in birds.

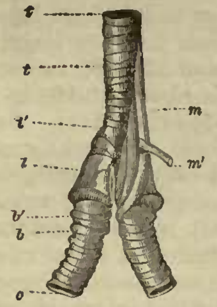

Fig. 75.—Larynx of a Rook.

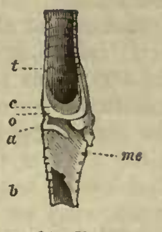

Fig. 76.—Vertical section of the same.

bronchial tubes, *b b'*, each of which has its own glottis and vocal cords; the inner lip of one of these is seen at *a* (fig. 76); and at *me* is shown a drum-like membrane, forming the inner wall of the bronchial tube, which probably increases the resonance of the voice. These parts are acted on by several muscles, the number of which varies according to the compass and flexibility of the voice in the different species; being very considerable in the most esteemed of the singing-birds, and being reduced to a small amount in those which have no vocal powers. In some, indeed, they are altogether absent; and the state of the glottis can be influenced only by those muscles which raise and lower the whole trachea.

467. The vocal sounds produced by the action of the larynx are of very different characters; and may be distinguished into the *cry*, the *song*, and the ordinary or acquired *voice*. The *cry* is generally a sharp sound, having little modulation, or accuracy of pitch, and being usually disagreeable in its timbre or quality. It is that by which animals express their unpleasing emotions, especially pain or terror; and the human infant, like many of the lower animals, can utter no other sound. In *song*, by the regulation of the vocal cords, definite and sustained musical tones are produced, which can be changed or modulated at the will of the individual. Different species of birds have their respective songs; which are partly instinctive, depending upon the construction of their larynx, and are partly governed by their education. In Man, the power of song is entirely acquired; but, when once acquired, it is far more susceptible of variety and expression than that of any other animal. In fact, the larynx of Man may be said to be the most perfect musical instrument ever constructed. The *voice* is a sound more resembling the cry, in this—that it does not consist of sustained musical tones; but it differs from the cry, both in the quality of its tone and in the modulation of which it is capable by the will. In ordinary conversation, the voice passes through a great variety of musical tones, in the course of a single sentence, or even a single word—sliding imperceptibly from one to another; and it is when we attempt to fix it definitely to a certain pitch, that we change it from the *speaking* to the *singing* tone.

468. It is to the wonderful power that Man possesses, of producing *articulate* sounds, which form a medium by which he can communicate ideas of any kind to his fellows, that much of his superiority to other animals is due. Nevertheless, it is not to this alone that we must attribute it; for many animals, especially birds, can produce, by *imitation*, sounds as articulate as those of Man; but the *mind*, which originates them, and which uses them as expressions of its ideas and desires, is deficient.

469. All spoken language is made up of a certain number of *elementary sounds*, which are combined into syllables, words, and sentences. It may be easily shown, upon arithmetical principles, that from twenty or more of these elementary sounds, an almost infinite variety of combinations may be produced; and, from such an inexhaustible store, there is no difficulty in deriving new combinations to represent any new ideas that we may desire to express. These simple or elementary sounds ought to be represented by an equal number of single letters; this is the case, however, in but few languages. Our own is particularly faulty in this respect; for there are many simple sounds that can be only represented by a combination of letters; while others may be represented by more than one single letter; and, in some instances, a single letter represents a composite sound.

470. Vocal sounds are divided into vowels and consonants; the true distinction between which appears to be, that the vowel sounds are *continuous tones*, modified by the form of the aperture through which they pass out; while, in giving utterance to consonants, there is a partial or complete interruption to the breath, in its passage through the organs in front of the larynx. Hence all true vowels may be prolonged for any length of time that the breath is supplied from the lungs; while the sound of many consonants is momentary only.

471. The study of the mode in which the different consonants are produced, is of particular importance to those who labor under defective speech, especially that difficulty which is known as *stammering*. This very annoying impediment is occasioned by a want of proper control over the muscles concerned in articulation, which are sometimes affected with a kind of spasmodic action. It is in the pronunciation of the consonants of the explosive class that the stammerer usually experiences the greatest difficulty; for the total interruption to the breath which they occasion is frequently continued involuntarily, so that either the expiration is entirely checked, or the sound comes out in jerks. Sometimes, on the other hand, in pronouncing vowels and continuous consonants, the stammerer prolongs his expiration, without being able to check it. The best method of curing this defect (where there is no malformation of the organs of speech, but merely a want of power to use them aright,) is to study the particular defect under which the individual suffers; and then to make him practice systematically the various movements concerned in the production of the sounds in question, at first separately, and afterwards in combination, until he feels that his voluntary control over them is complete.

472. The apparatus by which the sounds of Insects are produced is very different from that which exists in Mammalia and Birds. It varies greatly in different classes of Insects. In some, as in the common Cricket, the shrill note is produced by the rubbing of the wing-cases against each other. In the Cicada (improperly called Locust) of the United States, the loud and piercing note of which may be heard at a great distance, the vocal organs are placed on the underside of the body, between the base of the hind-legs and the abdomen; and consist externally of a pair of large flattened plates of a horny texture, varying in form in the different species. When these are raised, they are found to conceal a large cavity partially covered with a membrane of much more delicate nature than the external covering, with a horny plate in the middle, which lies along the bottom. Still more internally are two bundles of muscles, which are the real agents in producing the sound; for, when they are pulled, and suddenly let go, even in a dead specimen, the sound is produced as well as though the insect were alive. They act by drawing in and forcing out, by their alternate and rapid contraction, a horny *drum* or membrane, stretched in such a manner as to vibrate readily; the sound occasioned by the movements of which passes out through an aperture resembling the sound-holes of a violin.

CHAPTER XIV.

INSTINCT AND INTELLIGENCE.

473. It will be remembered that, when the Nervous System was described (Chap. ix.), it was shown to be the instrument of three classes of operations, each of which seems to be performed by a distinct portion of the system: I. The first of these is the class of *Reflex* actions, which are executed only in respondence or answer to the impression made by certain agents operating upon the nerves proceeding to a ganglionic centre; as when a water-insect, whose head has been cut off, executes swimming movements, immediately that its feet come in contact with water. These actions are evidently performed without any choice or direction on the part of the animal, which, in executing them, seems like a mere machine, adapted to perform certain actions when certain springs are touched; and it has been shown that they may take place, even without its consciousness. Of these reflex movements, the Spinal Cord in Vertebrata, and in Invertebrata (Insects, &c.), the ganglia corresponding to it (in regard to their connexions with the organs of locomotion, respiration, &c.) are the instruments (§ 474). II. The second class comprehends the Instinctive and Emotional actions, which differ from the preceding, in being dependent on the *Sensations* received by the animal, and in being, therefore, never performed without its consciousness. Nevertheless,

§ 467. How may vocal sounds be divided?—What is said of the *cry?*—What of the *song?*—What of the *voice?* 468. What is said of the superiority of Man over other animals, as connected with his power of producing articulate sounds? 469. What is said of elementary sounds?—In what respect is the English language faulty? 470. How are vocal sounds divided?—How do vowels differ from consonants?

§ 471. What is said of stammering?—By what is it occasioned?—What effect does it produce on the pronunciation?—How may it be remedied? 472. What is said of the sounds of insects?—How is the note of the Cricket produced?—Describe the apparatus by which the song of the Cicada is produced? 473. What is the first class of operations of which the nervous system is the instrument?—What is said of reflex actions?—What parts of the nervous system are the especial instruments of these actions?

the animal, in executing them, is not guided by any perception of the object to be attained, or by any choice of the means by which it is accomplished; but acts blindly and involuntarily, in accordance with an irresistible impulse implanted in it by its Creator for the purpose of doing that, *without* or even *against* its will, which it would not have devised by its very imperfect intelligence. The actions of this class are most wonderful in the Invertebrata, which possess the least intelligence; and, on the contrary, they are fewest and least remarkable in man, whose intelligence is highest. From the constant proportion which they bear to the size of the ganglia of sensation, which form nearly the whole nervous mass in the head of insects, &c., and a large part of that of the lower Vertebrata, but which are comparatively small in the Mammalia, and especially in man, there seems good reason to regard these organs as their chief instruments.

474. III. The third and highest class of actions, is that in which intelligence is the guide, and the will the immediate agent. The animal receives sensations, forms a notion of their cause, reasons upon the ideas thus excited, perceives the end to be attained, chooses or devises the means of accomplishing it, and voluntarily puts those means into execution. These actions are seen, in their highest and most complete form, in man; but they are not confined to him; for, as will be shown hereafter, true reasoning processes are performed by many of the lower animals. There can be no doubt that the cerebral hemispheres, which form the *brain* properly so called, constitute the instrument by which these actions are executed; for we find their size and development bearing a very regular proportion to the degree of intelligence which the animal possesses.

475. The *first* class, that of Reflex Movements, has been already considered in sufficient detail; but it is intended, in the present chapter, to offer some examples of those of the *second* and *third* class; those actions, namely, which are guided by *Instinct* and *Intelligence* respectively. These actions may be usually distinguished by the two following tests: 1. Although, in most cases, experience is required to give the will command over the muscles concerned in its operations, no experience or education is required, in order that the different actions, which result from an instinctive impulse, may follow one another with unerring precision. 2. Instinctive actions are performed by the different individuals of the same species, nearly, if not exactly, in the same manner; presenting no such variation of the means applied to the objects in view, and admitting of no such improvements in the progress of life, or in the succession of ages, as we observe in the habits of individual men, or in the manners and customs of nations, which are for the most part adapted to the attainment of particular ends, by voluntary efforts guided and directed by reason. Where, as in the examples hereafter to be mentioned, we find individual animals "learning wisdom by experience," and acquiring the power of performing actions which do not correspond with their natural instincts, we cannot do otherwise than regard them as possessed of a certain degree of intelligence, by which they are rendered susceptible of education.

476. The *amount* of intelligence displayed in these acquirements, can only be judged of, however, by carefully examining the circumstances under which they are made. If the new habits are gained by imitation simply—as is the talking of a Parrot—no great degree of intelligence is manifested; but if it spontaneously result from a reasoning process on the part of the animal, our idea of its sagacity is raised. There may be a combination of both these conditions; as in the following curious circumstance: Some horses, kept in a paddock, were supplied with water by a trough, which was occasionally filled from a pump—not, however, as often as the horses seem to have wished; for one of them learned, of his own accord, to supply himself and his companions, by taking the pump-handle between his teeth, and working it with his head. The others, however, appear to have been less sagacious, or more lazy; and, finding that this one had the power of supplying their wants, they would tease him, by biting, kicking, &c., until he had pumped for them, and would not allow him to drink until they were satisfied. That this was not a mere act of *imitation*, appears from the circumstance, that the horse did not attempt to imitate the movement of the man, but performed the same action in a different manner; evidently because it had *associated* in its mind the motion of the pump-handle with the supply of water.

477. The Instincts of Animals may be shown to have immediate reference, probably in every instance, to the supply of the wants of the individual, or to the continuance of the race. Thus, we have instincts which guide in the selection and acquirement of food; others which govern the construction of habitations for the individual, and of receptacles for the eggs—and these may influence a number at once, in such a manner as to unite them into a society; others which direct their emigrations, whether in search of food, for the deposit of their eggs, or for other purposes. Of these, some examples will now be given.

Fig. 77.—Ant Lion, in perfect state.

478. Among the instincts which direct animals in the acquirement of their food, few are more remarkable than those possessed by the larva of the *Ant-lion*, a small insect allied to the Dragon-fly. This animal is destined to feed upon ants and other small insects, whose juices it sucks; but it moves slowly and with difficulty; so that it could scarcely have obtained the requisite supply of food, if nature had not guided it in the construction of a remarkable snare, which entraps the prey it could not acquire by pursuit. It digs in fine sand a little funnel-shaped pit (fig. 79), and conceals itself at the bottom of this, until an insect falls over its edge; and if its victim seeks to escape, or stops in its fall to the bottom, it throws over it, by means of its head and mandibles, a quantity of sand, by which the insect is caused to roll down the steep, within reach of its captor. The manner in which the Ant-lion digs this pit is extremely curious. After having examined the spot where it purposes to establish itself, it traces a circle of the dimensions of the mouth of its pit; then, placing itself within this line, and making use of one of its legs as a spade, it digs out a quantity of sand, which it heaps upon its head, and then, by a sudden jerk, throws this some inches beyond its circle. In this manner it digs a trench, which serves as the border of its intended excavation, moving backwards along the circle, until it comes to the same point again; it then changes sides, and moves in the contrary direction, and so continues until its work is completed. If, in the course of its labors, it meets with a little stone, the presence of which would injure the perfection of its snare, it neglects it at first, but returns to it after finishing the rest of its work, and uses all its efforts to get it upon its back, and carry it out of its excavation; but if it cannot succeed in this, it abandons its work, and commences anew elsewhere. When the pit is completed, it is usually about three inches in diameter, by two in depth; and when the inclination of its walls has been altered by any slip, as almost always happens when an insect has fallen in, the Ant-lion hastens to repair the damage.

Fig. 78.—Larva of the Ant-Lion.

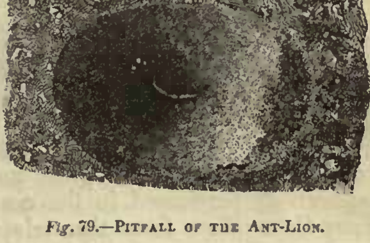
Fig. 79.—Pitfall of the Ant-Lion.

479. Snares of a still more singular character are constructed by many Spiders, which spin webs of the finest silk for the purpose of entrapping their prey. The arrangement of these toils varies according to the species, and sometimes does not present any regularity; but in several instances it is of extreme elegance; and no one can watch the labors of a common garden-spider, without being struck

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§474. What is the second class of these operations?—What is said of the instinctive and emotional actions?—In what animals are these actions most wonderful?—What parts of the nervous system are their chief instruments?—What is the third and highest class of actions?—Explain the process by which these are accomplished?—Are these actions confined to man?—What is the instrument by which these actions are executed? 475. How may those actions which are guided by instinct be distinguished from those which are guided by intelligence?—When animals "learn wisdom by experience," are they guided by instinct alone? 476. What actions display the highest degree of intelligence; those which arise from imitation simply, or those which result from a reasoning process?—Relate the anecdote of the horses, in illustration.

§477. What operations of animals are guided by instinct? 478. Describe the mode adopted by the Ant-lion for the acquirement of its food, the making of its pitfall, &c. 479. What is said of the construction of its web by the Spider?

with the marvellous sagacity which it displays in the execution of its work, and the perfection with which its web is constructed.

480. An equally curious instinct is often displayed in the construction of the habitations which the animal designs for its abode. Thus the Hamster, a small animal allied to the Rat, which is met with in most cultivated districts of Europe, and which is very injurious to agriculture, constructs a burrow in the soil, which has always two openings—one in an oblique direction, which serves the animal for casting out the earth it has dug away; the other perpendicular, which is the passage by which it enters and makes its exit. These galleries lead to a regular series of circular excavations, which communicate with each other by horizontal passages; one of these cavities, furnished with a bed of dried herbage, is the abode of the Hamster; and the others serve as magazines for the provisions, which it collects in large quantities.

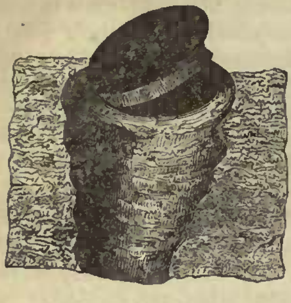
Fig. 80.—Nest of Mygale.

481. There are certain Spiders known to zoologists under the name of *Mygales* which perform operations analogous to those of the Hamster, but still more complicated; for not only do they excavate in the ground a large and commodious habitation, but they line it with a silken tapestry, and furnish it with a door regularly hung upon a hinge. For this purpose, the Mygale digs, in a clayey soil, a sort of cylindrical pit, about three or four inches in length, and plasters its walls with a very consistent mortar. It then constructs, of alternate layers of earth, and of threads woven into a web, a trap-door exactly adapted to the orifice of its hole, and only capable of opening outwards; and it attaches this by a hinge of the same thread to the tapestried lining of its chamber. The outside of this trap-door is covered with materials resembling the soil around; and so little does it differ from this, that it is with difficulty distinguished, even by a person seeking to discover the spider's habitation. If an attempt is made to lift it, when the animal is within its excavation, the effort is resisted by the whole force of the spider, which holds down the door, by fixing its claws into small holes on its under surface, at the point most distant from the hinge, where its force may be most advantageously applied.

482. Among Insects, we find a great number of very curious processes, instinctively performed in the construction of their habitations. Many Caterpillars form themselves a protection, by rolling together portions of leaves, and attaching them by threads. In almost every garden we may observe (at the proper season) nests of this kind, on the leaves of the lilac or gooseberry. The larva of the little Clothes-moth, again, forms a sort of tubular sheath, composed of the filaments it detaches from the stuff, through which it excavates its galleries; this sheath it is continually prolonging at one extremity; and when, in consequence of the growth of the larva, its tube becomes too small for its comfortable residence, it slits it down, and lets in a piece. The aquatic larvæ of the Caddice-flies, which are commonly known as *Caddice-worms*, house themselves in straws, pieces of hollow stick, small shells, &c., so as to make a tube, in which the animal creeps along the bottom and sides of the brook it inhabits, and sometimes rows itself on the surface of the water. When full-grown, the larvæ attach their cases to some large stone by threads; and then close the mouth of the case with an open net-work of threads, sufficiently close to prevent the entrance of insects, but with meshes permitting the water to pass through. In this state they undergo their metamorphosis into the Pupa state; and, a short time before their last metamorphosis, they cut the threads of the net-work by means of two hooks, with which their heads are furnished, and creep out of the water; soon after which they change into the perfect insect.

483. It is scarcely possible to point to any actions better fitted to give an idea of the nature of instinct, than those which are performed by various insects, when they deposit their eggs. These animals will never behold their progeny, and cannot acquire any notion from experience, therefore, of that which their eggs will produce; nevertheless, they have the remarkable habit of placing, in the neighborhood of each of these bodies, a supply of aliment fitted for the nourishment of the larva that is to proceed from it; and this they do, even when they are themselves living on food of an entirely different nature, such as would not be adapted for the larva. They cannot be guided in such actions by any thing like *reason;* for the data on which alone they could reason correctly, are wanting to them; so that they would be led to conclusions altogether erroneous, if they were not prompted, by an unerring *instinct,* to adopt the means best adapted for the attainment of the required end.

484. Of this kind of instinct, the *Necrophorus*, a kind of Beetle, not uncommon in our fields, offers a good example. When the female is about to lay her eggs, she seeks for the dead body of a Mole, Mouse, or such other small quadruped; and, having found one, she excavates beneath it a hole of sufficient dimensions to contain the body, which she gradually drags into it; she then deposits her eggs in the carcase, so that the larvæ, when come forth, find themselves in the midst of a supply of carrion, on which they feed, like their parents. This instinct is still more remarkable, when an insect, whose diet is exclusively vegetable, prepares for its larva a supply of animal food. Such is the case with the *Pompilus*, an insect allied to the Wasp. In its perfect state, it lives entirely on the juices of flowers; but the larvæ are carnivorous; and the mother provides for them the requisite supply of the food they require, by placing in the nest, by the side of the eggs, the body of a Spider or Caterpillar, which she had previously killed by means of her sting. The *Xylocopa* or Carpenter-Bee, has very analogous habits; the female makes long burrows in wood, palings, &c., in which she excavates a series of cells; and in every one of these she deposits an egg, with a supply of pollen-paste.

Fig. 81.—Xylocopa.

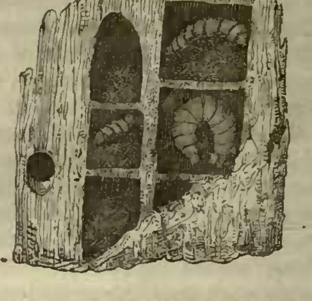
Fig. 82.—Nest of Xylocopa.

485. The instinct of support and protection to the young and helpless offspring, is seen in all animals in which it is needed; and it is particularly observable in Birds. The nests which they construct are destined much more for the reception of their eggs, and for the protection of the young, than for their own residence; for there are few birds which pass much time in their nests, except at night, and during the period of incubation. It is impossible to watch the process of their construction, without admiring the perseverance with which these interesting animals bring together the materials that are destined for their erection, and the art with which they are arranged. The form and structure of these habitations are always nearly the same, among the individuals of the same species; but there is necessarily a certain latitude in regard to the materials of which they are composed, since the same could not be every where procured. The nests of different species vary greatly, however, both as to form, structure, and materials; and these are admirably adapted to the particular circumstances in which the young families are respectively destined to live. Sometimes these habitations are constructed of earth, the particles of which are united by the viscid saliva of the bird, into a tenacious mortar; and they are then commonly built

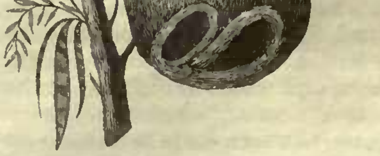
Fig. 83.—Nest of the Baya.

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§480. Describe the construction of the habitation of the Hamster. 481. Describe the operations of the Mygale, in digging its pit and hanging its trap-door. 482. Describe the processes of Caterpillars, of the Clothes-moth, of the Caddice-worm, in the construction of their habitation. 483. What is said of the actions of insects in depositing their eggs?

§484. What examples of this kind of instinct are given. 485. What is said of the instinct of support and protection of the offspring as observed in birds?—Describe the construction of their nests.

against the sides of a rock or wall. But, in general, they are constructed of sticks, straws, and other vegetable substances, and are placed either on the ground, or among the branches of trees. The greater number of them have a somewhat hemispherical form, resembling a little round basket; and their interior is lined with moss and down.

Fig. 84.—Nest of the Tailor-bird.

486. But sometimes the arrangement is much more complicated, in order that some particular danger may be avoided, or some special purpose answered. Thus the nest of the Baya, a little Indian bird allied to the Bulfinch, has the form of a bottle; and it is suspended from a twig of such slenderness and flexibility, that neither monkeys, serpents, or squirrels can reach it (fig. 83). That it may be still more secure against the attacks of its numerous enemies, the bird forms the entrance of the nest on its under side, so that it can itself only reach it by the aid of its wings. This curious habitation is constructed of long grass; and several chambers are found in its interior, of which one serves for the female to sit on her eggs, while another is occupied by the male, who solaces his companion with his song, while she is occupied in maternal cares. Another curious nest is that of the *Sylvia sutoria*, or Tailor-bird (fig. 84), a little Eastern bird allied to the linnet; which, by the aid of filaments of cotton drawn from the cotton-plant, sews leaves together with its beak and feet, in such a manner as to conceal the nest, which they inclose from the observation of its enemies.

487. The association of a number of individuals of certain species, for the performance of labors in which they all unite to one common end, is another most remarkable example of the operation of instinct. Several Mammalia exhibit this tendency in a greater or less degree; but the most interesting of all, in this point of view, is the Beaver, which is now chiefly found in the remote western and northern parts of North America. During the summer, it lives solitary in burrows, which it excavates for itself on the borders of lakes and streams; but as the cold season approaches, it quits its retreat, and unites itself with its fellows, to construct, in common with them, a winter residence. It is only in the most solitary places that their architectural instinct develops itself. Having associated in troops of from two to three hundred each, they choose a lake or river, which is deep enough to prevent its being frozen to the bottom; and they generally prefer running streams, for the sake of the convenience which these afford in the transportation of the materials of their erection. In order that the water may be kept up to a uniform height, they begin by constructing a sloping dam; which they form of branches interlaced one with another, the intervals between them being filled up with stones and mud, with which materials they give a coat of rough-cast to the exterior also. When the dam passes across a running stream, they make it convex towards the current; by which it is caused to possess much greater strength than if it were straight. This dam is usually eleven or twelve feet across at its base, and it is enlarged every year; and it frequently becomes covered with vegetation, so as to form a kind of hedge.

488. When the dam is completed, the community separates into a certain number of families; and the beavers then employ themselves in constructing huts, or in repairing those of a preceding year. These cabins are built on the margin of the water; they have usually an oval form, and an internal diameter of six or seven feet. Their walls are constructed, like the dam, of branches of trees; and they are covered, on two of their sides, with a coating of mud. Each has two chambers, one above the other, separated by a floor; the upper one serves as the habitation of the beavers, and the lower one as the magazine for the store of bark which they lay up for their provision. These chambers have no other opening than one by which they pass out into the water. It has been said that the flat oval tail of the beavers serves them as a trowel, and is used by them in laying on the mud of which their erections are partly composed; but it does not appear that they use any other implements than their incisor-teeth and fore-feet. With their strong incisors they cut down the branches, and even the trunks, of trees which may be suitable; and, by the aid of their mouths and fore-feet, they drag these from one place to another. When they establish themselves on the banks of a running stream, they cut down trees *above* the point where they intend to construct their dwellings, set them afloat, and, profiting by the current, direct them to the required spot. It is also with their feet that they dig up the earth they require for mortar, from the banks or from the bottom of the water. These operations are executed with extraordinary rapidity, although they are only carried on during the night. When the neighborhood of man prevents the beavers from multiplying to the degree necessary to form such associations, and from possessing the tranquillity which they require for the construction of the works now described, they no longer build huts, but live in excavations on the banks of the water.

489. It is among Insects that we find the most remarkable examples of this kind of social instinct; and the structures which are produced by the united labors of a large number, working together in harmony, are extremely interesting. The nests of Wasps are constructed in this manner. In order to form the materials for building them, these insects detach with their mandibles the fibres of old wood, which they convert by mastication into a sort of pulp, that hardens into the consistence of pasteboard; of this substance they construct several ranges of hexagonal *cells;* and the *combs* thus formed are arranged parallel to each other at a regular distance, and are united at intervals by little columns which serve to suspend them. The whole is either hung in the air, lodged in the hollow of a tree, or buried in the ground; and it is sometimes inclosed in a general envelop, sometimes left uncovered, according to the species.

490. The same community of labor is observed in the ordinary hive-Bees, which present to the intelligent observer a source of interesting occupation that scarcely ever fails. The number and variety of instincts, each of them most perfectly adapted to the end in view, which these insects exhibit, is most wonderful; and many volumes have been written upon them, without by any means exhausting the subject. Only a single example of these can be stated here; but the illustration it affords of the general remarks heretofore made upon the nature of instinct, is too valuable to be passed by. Each hive contains but a single queen; and she is the only individual capable of laying eggs. There are usually from six hundred to eight hundred males or drones, and from ten thousand to thirty thousand neuters or working-bees. In their natural condition, they live in the hollows of trees; but they appear equally ready to avail themselves of the habitations prepared for them by man. The cells, of which their combs are composed, are built up of the material that we term *wax*. Of this, a part may be obtained direct from plants, since it is secreted in greater or less abundance by several species; but there seems to be no doubt that bees can elaborate it for themselves from the materials of their aliment. The wax is separated in little scales, from between the segments of the abdomen; these scales are kneaded together by the mandibles of the insect, and are then applied to the construction of the cells. It is easy to understand, that the hexagonal form is that which enables the cells to be best adapted to the purposes for which they are built, while the least amount of material is expended. As they are intended not only to contain a store of honey, but also to serve as the residence for the larvæ and pupæ, it is evident that their form must approach near to that of the cylinder, in order that there may be the greatest economy of space; but it is also evident that, if their walls were circular, a large quantity of material would be required to fill up the interspaces between them; while, by giving the cells the hexagonal form, their walls every where have the same thickness, and their cavity is sufficiently well adapted to the forms of the larva and grub.

491. Every comb contains two sets of cells, one opening on each of its faces. The cells of one side are not exactly opposite, however, to those of the other; for the middle of each cell abuts against the point, where the walls of three cells meet on the opposite side; and thus the partition that separates the cells of the opposite sides is greatly strengthened. This partition is not flat, however, but consists

§ 486. Describe the nest of the Baya.—That of the Tailor-bird. 487. What is said of the association of animals for one common purpose?—What animal possesses this instinct in a remarkable degree?—Describe the operations of the Beaver, in building its dam. 488. Describe the construction of the Beaver's hut, &c.

§ 489. What is said of the social instinct among insects?—How are the nests of Wasps constructed? 490. What is said of the variety of instincts exhibited by Bees?—Describe the economy of a bee-hive, the mode of making wax, the arrangement of the cells, &c. 491. What is said of the construction of the partitions of the cells of the honey-comb?—State the wonderful coincidence between the practice of the Bee and the theory of the mathematician, in the mode of constructing these partitions.

of three planes, which meet each other at a particular angle, so as to make the centre of the cell its deepest part. Of the three planes which form the bottom of each cell, one forms part of the bottom of each of the three cells, against which it abuts on the opposite side, as shown in the accompanying figure. Now, in order to combine the greatest strength with the least expenditure of material, the edges of these planes must form with each other certain invariable angles. By the very intricate mathematical calculations of Koenig, it has been determined that these conditions are fulfilled,—that is, the greatest strength is attained by using the least material—when the amount of one of these angles is 109° 26′, and that of the other 70° 34′. Upon measuring the amounts of the angles actually used by the bee in the construction of its partition, one was found to be 109° 28′, and the other 70° 34′—a coincidence between the theory of the mathematician and the practice of the bee (untaught, save by its Creator), which has been ever regarded as truly marvellous, and as affording one of the most remarkable examples of the operation of instinct. The very small discrepancy, amounting to only two minutes of a degree (or 1-10,800th part of the whole circle), has been usually supposed to result from a slight error in the measurement of the angle employed by the bees; but Lord Brougham, not satisfied with this explanation, has recently applied himself to a fresh investigation of the question; and he has shown that, owing to the neglect of certain small quantities, the theoretical result obtained by Koenig was erroneous, to the exact amount of two minutes; so that the bees proved to be right, and the mathematician wrong.

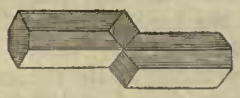

Fig. 85.—HEXAGONAL CELLS, SHOWING THE MANNER OF UNION AT THE BASE.

492. The amount of reasoning power possessed by some among the lower animals, may be considered as very much upon a par with that exhibited by an intelligent child, about the time when it is learning to speak. One of its first exercises is in the connexion of *association* of ideas; such as is shown in the following instance: A wren built its nest in the slate quarries at Penrhyn, Wales, in such a situation as to be liable to great disturbance from the occasional explosions. It soon, however, learned to quit its nest, and fly to a little distance, on the ringing of the bell which warned the workmen. This was noticed, and was frequently shown to visitors, by ringing the bell when there was not to be an explosion; so that the poor bird suffered many needless alarms. It at last learned, however, that the first notion it had formed, by the association of the ringing of the bell with the explosion, was liable to exceptions; and it formed another more correct; for it was then seen that the wren did not leave its nest, unless the ringing of the bell was followed by the moving away of the workmen.

493. A similar process of association, carried rather further, but still quite simple enough to be readily believed, is shown in two dogs, which have been taught by their master to play at dominoes, and which go through the game with another person (under circumstances which render the idea of collusion with their master impossible) with the utmost regularity and correctness; not only playing rightly themselves, but watching to see that their adversary does so too. This, also, is a feat which a very young child might be taught to perform. A third instance has reference to the patient endurance of bodily pain, in opposition to the instinctive tendency to struggle against the infliction of it, and evidently occasioned by a voluntary effort on the part of the animal, made by it in obedience to the dictates of its reason. Dr. Davy mentions having seen an elephant, in India, that was suffering under a deep abscess in its back, which it was necessary to lay open, in order to effect a cure. "He was kneeling down, for the convenience of the operator, not tied; his keeper was at his head. He did not flinch, but rather inclined towards the surgeon, uttering a low suppressed groan. He seemed conscious that what was doing was intended for his good; no human being could have behaved better; and so confident were the natives that he would behave as he did, that they never thought of tying him." It were much to be wished, that all human beings would imitate this docile elephant's self-control. It appears, then, on the whole, that the mind of man differs from that of many of the lower animals rather as to the *degree* in which the reasoning faculties are developed in him, than by any thing peculiar in their *kind*. Among the more sagacious quadrupeds, it is easy to discover instances of reason as close and prolonged as that which usually takes place in early childhood.

CHAPTER XV.

HYGIENE, OR THE PRESERVATION OF HEALTH.

494. All organized beings are characterized, during the natural period of their existence, by an uninterrupted series of changes. Each organ and each tissue is constantly undergoing some transition of its elements, or performing some action. With the termination of life, all the natural phenomena that characterized the action of the various organs and the growth of the tissues, cease, and decomposition finishes the work of reducing an organized body to inanimate matter. Such is the constant tendency of all the parts of the body to undergo change, or to decompose, that the phenomena of life have been regarded as a continuous struggle against death. Such a view of life seems not inconsistent with the general character of man's existence. A large majority of the race yield the contest before their organization attains its perfection, while but few live out their full period in the enjoyment of an uninterrupted flow of life-giving changes.

495. The perfect performance of all the functions of life constitutes health. Impaired condition of an organ or tissue constitutes disease. Health is that natural condition in which each individual possesses the highest possible amount of physical happiness, and accomplishes most perfectly the high purposes of life. The capacity for happiness and usefulness is alike dependent upon the uninterrupted enjoyment of health, and its duration is the measure of life itself. In proportion as health is impaired, life becomes a burden, to be borne with less and less of comfort and happiness. How to preserve health, and thus prolong life, is therefore to each individual a question of paramount importance.

496. To maintain the body in a state of health, requires the exercise of an art (sometimes called Hygiene), founded upon the physiological principles by which the organs are governed. If our knowledge of physiology were perfect, the art of preserving health would require little skill for its practice. This, however, is far from being the case. Various unknown causes are in constant operation to interfere with and disturb the laws of healthy vital action, and render more or less uncertain any rules that might be adopted. Still, the Art of Preserving Health approaches nearer to a science, in the same ratio that physiology and chemistry become better understood. As our knowledge of these sciences increases, we learn to refer more and more of those changes that characterize living beings to general laws expressive of certain uniform conditions. For example, it is a fact of universal application, that a large mixture of carbonic acid in the air to be respired is prejudicial to life, and an obvious law follows. But it is not a fact of the same universal application that a given dose of a purgative medicine will produce an increased action of the bowels. A physician, in directing the ventilation of a room for the benefit of his patient, is guided by a high scientific principle; while, in administering a medicine, he is pursuing an art derived from experience. A knowledge of the body and its functions, with the properties of all the agents that affect it, must be guided by some observation or experience, of the effects those agents produce. Science and experience will then lend their mutual aid for the preservation of health.

497. The increased attention that has been given to Physiology, of late, has had an important influence in prolonging the duration of human life, as already shown by various tables of mortality; and there is abundant reason to suppose that as men become better acquainted with their own organization, they will not only know how to take better care of themselves, but will be more observing of those agents that affect health, and the period of human life will be correspondingly increased. We are not to suppose, however, that any golden age is to arise, wherein disease shall cease to afflict our race, and men shall no longer become old, nor die. So many contingencies of necessity belong to the life of a being whose existence is checkered by so many fears, anxieties, and hopes, and exhausted by so many vicissitudes of care and labor, that liability to sickness, disease, and

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§ 492. What is said of the reasoning power of some of the lower animals?—What instance of the association of ideas in a bird is given? 493. What two other instances of the process of association are given?

§ 494. What is said of the constant changes undergone by the organs and tissues during life?—In consequence of this tendency to change, how have the phenomena of life been regarded?—What is said of such a view of life? 495. What constitutes health?—What constitutes disease?—What is said of the importance of the preservation of health? 496. What is said of the laws of health, of the uncertainty of their operation, and of their connexion with Physiology and Chemistry? 497. What are the results of an increased knowledge of Physiology?—Are we, therefore, to expect exemption from disease?—Why not?—What is said of the comparative superiority of other animals in exemption from disease, and how is this accounted for?

death, is, in a certain sense, a law of our nature. It is also true, that millions annually perish from a neglect of the conditions which Divine Wisdom has appointed as requisite for the preservation of the body from fatal disease; and millions more are constantly suffering pain and weakness that might have been avoided, by attention to those principles which it is the province of Physiology to unfold. Indeed, other animals enjoy more uniformity of health, with more perfect exemption from disease, pain, and suffering; and the duration of life to a given period, characteristic of each group, is correspondingly more certain to each individual. The comparative superiority of animals in exemption from disease is easily accounted for by the regularity of their habits. By the impulses of instinct, the animals are led to adapt those habits of life and those localities most favorable to their own individual organization. The same All-wise Being who created them has taught each the kind of diet and life to maintain. Each zone has animals peculiar to itself; and each animal is fitted, by peculiarities of structure, for a particular kind of diet upon which it invariably subsists. The Ox and Horse live only on herbage, grasses, grain, &c.; and the Lion, on the flesh of other animals. Insects, whose period of life, for the most part, is very brief, subsist only on particular vegetables, or on particular parts of some vegetable.

498. Man is the only animal that inhabits all climates, and possesses the power of changing his residence from one climate to another with impunity. He also enjoys a wider range of diet than any other. He is endowed with reason, and the faculty of learning by experience, to enable him to pursue those habits best adapted to promote health in the various localities he may inhabit. His food, for the most part, undergoes a process of cooking, to render it more easy of digestion. His clothing is prepared by his own hands, according to the climate to which he may be exposed. His early years, however, are characterized by entire dependence upon the condition in which he is placed for the future development of his frame; and it depends, in great part, upon the care with which he is tended, and the knowledge by which that care is guided, whether he shall grow up in health, and vigor of body and mind, or become weakly, and fall the victim of premature disease and death. Thus, man's system of life is almost wholly artificial, and his habits are varied, according to the knowledge and inclinations of each. In the supply of warmth, food, and air to the body, the greatest essentials to life, no uniformity prevails. The protection of the body, its nutriment, and its exercise, are all artificial. Nor is his diet restricted to the natural productions of the locality he may inhabit. Commerce brings to him the luxuries of all climates, and makes his table to groan under the burden of an unlimited variety that creates and pampers an artificial appetite. The fashions and customs of society are thus based on artificial systems of diet, dress, sleep, and labor; all tending to make the possession of health and the duration of life variable and uncertain. This will be seen, by comparing the tables of mortality in different localities, and in different classes of society in the same localities.

499. In the island of St. Kilda, the most northern of the Hebrides, eight out of every twelve children die between the eighth and twelfth day of their existence; and the population of the island is diminishing, rather than increasing. This is due to the filth in which the inhabitants live, and the noxious effluvia which pervade their apartments. During the space of twenty-one years, ending in the year 1796, in the Dublin Foundling Hospital, out of ten thousand two hundred and seventy-two sick children sent to the infirmary, only forty-five recovered. The cause of this most fearful mortality was deficient ventilation and improper food, with most criminal treatment on the part of the nurses. The children were fed by hand, and when they cried and became troublesome, they were dosed with laudanum, to keep them still—a result which it perfectly effected, for many of them never awoke. In another similar institution in Dublin, at the conclusion of the year 1782, out of seventeen thousand six hundred and fifty infants, two thousand nine hundred and forty-four, or nearly every sixth child, died within a fortnight after its reception. By improved ventilation of the wards, the mortality was speedily reduced to one in nineteen and one-half, instead of one in six. In London, during successive periods of twenty years, the following reduction of the average numbers of deaths among children under five years of age were made by increased attention to the physiological conditions requisite for health. In twenty years, from 1730 to 1750, out of every one hundred children born, seventy-four, or nearly three out of four, died before they were five years old. In the next twenty years, the number was reduced to sixty-three in one hundred, or less than two-thirds. Between 1770 and 1790, it was only fifty-one in one hundred, or little more than one-half. From 1790 to 1810, it was farther reduced to forty-one in one hundred, or little more than two-fifths. And between 1810 and 1830, it was no more than thirty-two in one hundred, or less than one-third.

500. Attention to the laws of life proves efficacious not only in diminishing mortality, but in promoting health. A remarkable case in point, is that of the Orphan Asylum in Albany, New York, which was opened in the end of 1829, with about seventy children, which number was subsequently increased to eighty. "During the first three years, when an imperfect mode of management was in operation, from four to six children were constantly on the sick-list; the physician was in regular attendance twice or thrice a week; and the deaths, for the three years, amounted to between thirty and forty, or about one in every month. At the end of this time, an improved system of management and diet was adopted. The sick-room was entirely vacated, and the services of a physician no longer needed, and for more than two years no case of sickness or death took place. It is also true, that, since the new regimen has been fully adopted, there has been a remarkable increase of health, strength, activity, vivacity, cheerfulness, and contentment, among the children. The change of temper is also very great; they have become less turbulent, irritable, peevish, and discontented, and far more gentle and kind to each other.

501. Every improvement that has taken place in regard to the physical condition of both infants and adults has been attended by a corresponding increase in the duration of life. Historical facts abundantly prove that the term of human life has undergone an increase since the last century. Tables, computed as the basis of life insurance seventy or eighty years ago, are found to have underrated the present duration of life very considerably. But the abodes of squalid poverty are still marked by a fearful mortality of the inmates; showing that filth, destitution, and wretchedness, court diseases. In France, the number of deaths among the poor is more than twice as great, in proportion to the whole number, as among those in easy circumstances. In England and Scotland, no more than one in fifty-eight, out of the whole population, now die every year; while, in Germany, the average is one in forty-five; in France, one in thirty-nine; in Turkey, one in thirty; in the Roman States, one in twenty-eight. In Franklin county, the most favorable to longevity of all the counties of Massachusetts, the average duration of life is about thirty-nine years; in the city of Boston, it is a little less than twenty-two and three-quarter years. Among foreigners, who constitute the poorest class in Boston, the average duration of life is only 13 5-10th years, or about one-third the average in Franklin county. Statistical facts are not wanting to prove that the scale of human life every where rises or falls with the physical condition of the people. The intelligent physician, as he goes the round of his daily calls in all grades of families, is constantly reminded of the contrast in health and happiness between those who observe an intelligent obedience to the rules of health, and those who live in careless ignorance of the laws of their own being, and are regardless of personal filth and exposure.

502. The natural period of man's life has been stated at seventy years; and this is, perhaps, near the true estimate; since almost all who die previous to that age are the victims of violence or disease. Thus, about one in thirty in those localities most favorable to longevity live out the appointed period of life, and go to their rest in a good old age; while twenty-nine-thirtieths are wasted by disease, or fall victims to accidental injury. In the cities, one-fourth of all that are born, die within the first year, and one-half during the first four or five years. In the country, the mortality of children is less, one-half surviving the first six years. The lowest rate of mortality is found among the convicts of our best regulated state-prisons. In the New Hampshire state-prison, where great attention has been paid to the diet of the prisoners, and ventilation of their apartments, the rate of mortality for thirty-six years is only one in seventy-nine; showing

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§ 498. What is said of the life and habits of man as contrasted with those of other animals?—What is the tendency of man's artificial system of life? 499. What is said of the mortality of children in St. Kilda, and how is it accounted for?—What other examples of mortality are given, what were their causes, and by what remedies was the amount of their mortality reduced?

§ 500. What is said of the sickness in the Orphan Asylum at Albany, and what have been the effects of an improved system of regimen and diet? 501. What other facts are given to show that the increase of the duration of life is dependent upon improvement in physical condition? 502, 503. What further statements are made in regard to this subject?—Where is the lowest rate of mortality said to be found?—What is the reason of this?

that the systematic care of their physical condition, in regard to diet, labor, and ventilation of their apartments, is some compensation for the privations of this most unfortunate class of persons.

503. Nothing is more certain than that communities are healthy and long-lived, just in proportion as their localities, occupations, and habits of life are favorable to these conditions. Individuals, in like manner, are blessed with health and long life, according to the vigilance and care they exercise over their physical habits. Health and life are blessings lent us only on certain conditions, or during obedience to those physical laws which are written on the bones, muscles, nerves, and all the organs of the body. Laws of our organization are more binding on us than the decalogue; since physical sin is without pardon or atonement; impaired health, and shortened life, are the irrevocable penalties of their violation.

504. Again, a very large proportion of those diseases that prove fatal, arise from avoidable causes. Nearly all acute or inflammatory diseases, and many chronic diseases, can be traced to some known cause that might have been avoided by a more intelligent care of the health. The age, too, at which a majority of the deaths occur, cannot be accounted for on any natural principles with which we are acquainted. No law of our nature has yet been discovered which would seem to indicate a necessity that one-half of all that are born in this country should fall victims of disease during the first five or six years. Indeed, every physician knows that, in the best-regulated families with which he is acquainted, no such mortality exists; and yet it is equally true, that even the best-regulated families have not reached any thing like perfection in observing the laws of health.

CAUSES OF PREMATURE DISEASE AND MORTALITY.

505. It is not possible, in the space proper to allot to this subject, to give any thing like a full account of the causes that operate to impair health and bring on a premature death. Many are of a general character, that exhaust and enfeeble the vital powers; such as insufficient supply of warmth, food, and air. Improper management in respect to these three great essentials of vitality prevails in all grades and classes of society. Among the affluent, the fashions of society forbid the use, in many instances, of proper clothing to protect the body against the inclemencies of a changeable climate; and the food is too great in quantity, or rich in quality; while, among the poor, still more suffering is induced by an insufficient supply of these necessaries. Insufficient ventilation of sleeping apartments, and too much confinement in doors; excessive labor and fatigue; or too constant occupation of the mind in study—all exert a depressing influence on the vital powers, and render the body susceptible to the attacks of disease, from the slightest causes. In persons that habitually suffer from bad air, improper clothing, or insufficient or improper nourishment, the blood becomes impoverished, or circulates imperfectly; and the functions of one or more organs become deranged, and disease speedily ensues.

506. Improper treatment of infants and children is a most prolific source of disease and premature death. It commences with the first hours of existence, follows the young child with unrelenting severity, and hurries off to a premature grave the very large proportion of one-fourth during the first year, and one-half in five or six years after birth (§ 500). A mortality so fearful and unaccountable on any natural principles, seems to call for special consideration. The first act of attention the young infant receives is to be clothed according to the prevailing fashion. Fortunately for the young of other animals, nature clothes them in garments adapted to their condition; but the young of the human species require artificial clothing, and this is too often made to please the eye, rather than to meet the wants of nature. When dressed according to the American fashion, it exposes to the admiration of friends, and the cold of a changeable climate, the breast, neck, and arms; and, in some instances, portions of the lower limbs are unprotected. Through the neck and breast, the lungs and respiratory passages are exposed to the almost direct action of the changes of the weather. The blood that circulates through the hands and arms is very superficial, nearly all the vessels lying just under the skin, and possessing but very slight natural protection against the influence of cold. Children thus dressed, are seldom without cold hands and arms. Hence, almost the entire mass of blood flowing from these parts is thoroughly chilled before it returns to the heart, where it mingles with the blood from the general circulation, and is thrown into the lungs to be again raised to its proper temperature by them, while their own heat is diminished by the external action of cold. Fortunately, however, the blood goes the round of the circulation so rapidly (§ 74), that an equilibrium is constantly maintained, and no very perceptible difference of temperature would be observed, except in the hands and arms; still, the true operation of this fashion of dressing children, on the blood, is in principle just as described. Indeed, there is not an equal extent of the entire surface of the unfortunate victim of fashion, that might not be left exposed in better accordance with its physical organization. In any other part of the body, the circulation is better protected, and would suffer less from exposure.

507. A much larger proportion of deaths among children occur during the winter months than any others of the year; showing that cold destroys more than any other cause. No period of life is so susceptible to the influence of cold, and at no period is the power of resisting it so feeble. Yet there is such a passion among American women to see the plump breast and round graceful arms of the young child, that multitudes fall victims to these vain fashions, notwithstanding every intelligent physician disapproves of the practice. A child, thus imperfectly protected against cold, will contract bronchitis, croup, inflammation of the lungs, or diseases of the digestive organs, from the most trivial exposure. A current of air at the sides of the closed window or door, so trifling as not to be noticed by an adult, is sufficient to induce a fatal disease in an exposed infant. Each winter makes known to our experience instances of severe inflammation of the respiratory passages, induced by the slightest exposure, in spite of the most watchful and anxious care in all things except one of the most essential—the dress.

508. Another fruitful source of mischief in the management of children, is excessive and improper food. Instead of allowing them only the aliment nature has designed, they are fed on a mixed diet of whatever they can be induced to swallow. An apology for depriving the young infant of the nutriment which an All-wise Creator has provided for it in the mother's milk, is found in disinclination, arising from false views of a mother's highest duty, or actual inability, from feeble health. Not less than three-fourths of the American women reared in our cities are incapacitated for discharging the duties of a mother, by impaired health. Their offspring inherit more or less of the same frailty of constitution, and are then put on an artificial system of diet, characterized by an ignorant and blind disregard of all true physiological principles, with the almost certain result of swelling the fearful bill of infantile mortality. Among the poor, children suffer from actual neglect, from undue exposure, and from bad or insufficient food. Among the affluent, they are too often committed to the care of hireling nurses, to be over-fed, or to be constantly surfeited with candies and luxuriant food. Among the middle classes of society, the mother is neither above nor below the care of her own child; and, as we might anticipate, the rate of the mortality of children is much lower in these than in any other class.

509. Among adults, the causes that induce disease are not unlike those that affect children. In this respect, "the child is father to the man." Those habits that render the child weak in health, and liable to disease, continue to act as direct agents, or as predisposing causes of disease. Those adults who have escaped the perils of childhood with vigorous health, too often waste it by excesses in sensual indulgence, or in bodily or mental labor, through the natural enthusiasm of impulsive youth. Thus, the strength which, carefully husbanded and sustained, might have kept the body and mind in activity and enjoyment up to the allotted period of "three score years and ten," is too frequently dissipated in early manhood.

510. Still, young men are exempted from evils that fall heavily on the other sex. While at school, the boy is allowed to follow the bent of his inclinations, during the intervals of study, and to seek in play that exercise which his nature imperiously demands. By this means, his body and its organs attain a certain development, though not as

§ 504. Do most diseases arise from accountable causes?—Is there any necessity for the death of so many children? 505. What remarks are made concerning the general causes of disease?—Mention some of these causes. 506. What is said of improper treatment of infants and children?—What of the fashionable mode of dressing children?—Explain the effect of this mode of dressing on the health.

§ 507. Mention other evil consequences produced by improper dressing of children. 508. What is another source of disease in children?—What is said of feeding children with improper food? 509. How may the health of adults be injured? 510. What is said of the difference between the management of boys and that of girls, as regards exercise?—What is the nature of the exercise usually permitted to girls, and why is it insufficient?

perfect as he might enjoy, if his education was conducted in strict accordance with physiological principles. The young miss of the boarding-school, on the other hand, as soon as she ceases to be a little girl, is discouraged from active exercise, as unbecoming her sex, and is taught to pass her leisure hours in a quiet, lady-like manner, at home, or in her room. If away at school, the only exercise she is permitted to take is a sedate, measured walk up and down the street, or around the square, once and occasionally twice a-day. At boarding-school, she is permitted still less of unrestrained and healthful exercise. The delicacy and refinement of her sex here become so great, that the restless activity of youth must be kept in check by the power of the matron or teacher, and her walk be taken in a solemn procession of her mates, two by two. A walk in a procession may afford some exercise to the limbs principally concerned in locomotion, but it is of very little benefit to the other organs of the body, while it certainly must fail to unbend and relax the mind.

511. Exercise, to benefit the young, must call into action all the muscles of the body as well as of the limbs; and it should also be of a character corresponding with the vivacity of youth—something into which the feelings and spirit can enter with enthusiasm and delight. An hour's exercise on a tread-mill, or in a walk, though better than none at all, does not meet the wants of the growing young of either sex. Hence a most marked difference can be seen between the countenances of those young ladies who are compelled to be "lady-like," and those who are permitted the unbounded and unrestrained pleasure of acting like little girls. By reference to tables of mortality, we find, on comparing the proportion of deaths among the two sexes, that the number of females who die between the ages of fifteen and thirty is greater than at any other period of life, and than that of males at the same period. Dr. Warren, of Boston, in a very excellent treatise on *Preservation of Health*, says, "In the course of my observations, I have been able to satisfy myself that about half the young females, brought up as they are at present, undergo some visible and obvious change of structure; and, of the remainder, a large number are the subjects of great and permanent deviations; while not a few entirely lose their health, from the manner in which they are reared." A physician and professor, who is now unquestionably the highest medical authority in the city of New York, gave it as his opinion, to his class, that three-fourths of the young ladies in the highest ranks of society are more or less deformed in structure, and impaired in health.

512. A late and most judicious French writer, speaking of lateral curvature of the spine, tells us that out of twenty young girls who have attained the age of fifteen years, there are not two who do not present very manifest traces of that species of deformity. The causes of spinal distortion, in general, are whatever weakens the constitution. Want of exercise, and improper dress, are the more immediate causes. It is a very remarkable fact, that where there is one case of lateral curvature of the spine among males, there will be, on an average, as many as nine among females. And it is equally worthy of thoughtful consideration, that the number of young ladies, between fifteen and twenty-five, who enjoy full and uninterrupted health, is very small, compared with the other sex; and yet it will be found that girls are quite as healthy as boys, so long as they are allowed the same amount of liberal exercise. The education of females, as now generally conducted, is a most prolific source of serious physical evil, terminating in premature death, or in feeble health during a life of impaired usefulness.

513. A love of life is inherent in each individual of the race; and no other earthly object can ever become more dear to the natural feelings of a sane mind, than the preservation of life. In consistency with this inborn desire to live, the preservation of health would seem a proper object of care and watchful thought on the part of each individual, and an object, too, in regard to which each would always possess the deepest solicitude to be fully and rightfully informed. Strange as it may seem, directly the opposite of what we would naturally expect, is true. There is no subject that pertains to our welfare, in reference to which we act so ignorantly, or with so little apparent thought and care. Most men seem to live in utter disregard of the laws of health, as if reckless of its preservation. Indifference to health is, therefore, one of the most prominent causes of premature mortality. It has its origin in most minds, either in the belief that a certain number of days or a certain length of life is preördained to each individual as his appointed period, which can neither be increased nor diminished by his own conduct; or, in other cases, there is so little apparent and immediate connexion between the violation and the penalty of physical laws, that they cannot be made to realize that a vicious habit can injure them, so long as they are not actually diseased—in other words, they can see no connexion between debilitating habits and wasted health, unless they experience a severe pain, or are thrown upon a bed of sickness, the instant they indulge in that which is injurious.

514. For instance, a student, who has been accustomed to much exercise, becomes unusually interested in his studies, and omits his daily exercise, without the least consciousness that his body is suffering, till, by and by, he becomes debilitated and feeble, and finally a confirmed invalid—a miserable sufferer throughout life. What is lost can seldom be regained. As time past never returns, so the vigor and energy of youth are never restored to a worn-out constitution. The transgressor is overtaken too late to be saved by repentance. The causes of disease are for a time latent—it may be unseen and unfelt. Its seeds are sown in the tissues and fluids of the body, stealthily, and often-times are not discovered till they have so far germinated as to be difficult of eradication.

515. Some of the general causes that produce disease have thus been mentioned; others will be considered in connexion with the means of preserving particular organs in health. The means of promoting health are general and special. General means, are those that improve the health of all the organs, such as exercise and bathing, which tend to invigorate the whole system, instead of confining their influence to particular organs. In a certain sense, all means are general; since whatever favorably affects a part, so far exerts a salutary influence on the whole body. But certain means have reference mainly to particular organs, and may therefore be considered as special means of preserving health. The organs of respiration and digestion, and the nervous system, have more to do with health than any others, and therefore require special consideration; while those of absorption, secretion, and excretion, are more general in their influence.

HYGIENE OF THE RESPIRATORY ORGANS.

516. The function of respiration consists in exposing the blood or circulating fluid to the action of atmospheric air (CHAP. IV.). It has for its object the purifying of the blood, and the generating of a certain amount of animal heat, which is produced by combining the oxygen taken into the lungs with the carbon and hydrogen in the tissues and fluids of the body. Nearly all our food contains more or less carbon, which is laid in store as the natural fuel to supply warmth to the body; and were it not for the existence of this constant demand for carbon, it would accumulate in large and injurious excess. By the process of respiration, carbon combines with oxygen to form carbonic acid, which is thrown from the lungs at each expiration. This work of purifying the blood, and producing heat, requires constant action of the lungs. The perfect performance of their function is more essential to vitality than that of any other organ, since the purity of the nutritive fluid depends on it. To insure health of the respiratory organs, the most important conditions are, that the lungs should at all times be free and unrestrained in their actions; that the blood itself should be presented to the lungs in as healthy a condition as possible, and that the temperature of all parts of the body should be nearly the same at all times.

517. To a reflecting mind, no argument would seem necessary to prove the importance of preserving the action of the respiratory organs free and unrestrained. It has been seen (§ 100, &c.), that the capacity of the lungs is increased and diminished by the alternate depression and elevation of the walls of the chest, together with the contraction and relaxation of the muscles of the abdomen. Whatever, therefore, constrains the free play of the walls of the abdomen

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§ 511. What kind of exercise is beneficial to the young?—Give the remarks of Dr. Warren, and of a New York physician, on the consequences of improper training of young ladies? 512. What are the remarks of a French writer on distortion of the spine among females?—What remarkable fact is stated, and to what cause is it attributed?—How may girls continue as healthy as boys? 513. What considerations are mentioned why the preservation of health would seem to be an object of solicitude?—What reasons are given for the carelessness of men in regard to their health?

§ 514. What illustration is given of ill-health produced without consciousness of the subject?—What other remarks are made? 515. Give the distinction between general and special means of preserving health.—What organs are most important in this connexion?—516. Review the process of respiration.—What conditions are mentioned as essential to the healthy action of the lungs? 517. Explain the play of the lungs in respiration, and show why tight dresses are injurious.—What remarks are made in regard to stays, &c.—What other effects of compression of the lungs are mentioned?

and the chest, interferes so much with the natural process of respiration. It is to be hoped that stays and corsets are now known only in the history of a less enlightened age. But a wasp-like waist still commands admiration; and though public sentiment has consigned to obscurity those mechanical instruments of disease, yet their place has been supplied by the thickly-set row of hooks and eyes. Any dress that will not hold together with very slight fastenings, and allow the same free expansion of the chest which nature permits, should be discarded as at war with health. Nor should any portion of a lady's or a gentleman's dress be so tight about the waist as to support its own weight. It does not belong to Physiology to teach the proper style of dress, but the principles of the science should be known by our mantua-makers and tailors; and the model of Grecian beauty should occupy a place in their diagrams of the latest fashions. Public lecturers and the press have exposed the evils of tight dressing, and some reform has followed; yet the great mass of our ladies, and many gentlemen, are still suffering from this plain violation of nature's laws Probably nine-tenths of our well-educated females, above twenty years of age, have suffered from deformity or weakness of the spine. How many of this number are afflicted with disease of the lungs, induced by constant compression of these vital organs, can never be known. Just in proportion as the lungs are constrained in their action does the respiration become more frequent—wearing out and exhausting the power of these organs, in the same manner that a piece of machinery will wear out faster when it is propelled beyond its appropriate velocity. It is owing to the diminished capacity of the respiratory organs, that persons tightly dressed can take only moderate exercise without inducing that hurried respiration called *panting*. The lungs seem struggling with intense effort to perform their office, while the whole system is suffering from the imperfect oxygenation of the blood. The extremities are habitually cold, and the countenance pale and sickly, from a feeble circulation of the vital fluid, and the subject becomes an invalid for life, or an early victim of disease.

518. The health of the lungs also depends, to a very great extent, on the purity of the blood. It should not be overcharged with carbon, or with any other impure matter. When the skin, the liver, or the kidneys, fail to perform their functions properly, the blood becomes loaded with injurious elements, tending to disease. It has been estimated (§ 217, &c.) that the average amount of daily exhalation from the skin of a healthy man is about two and a half pounds, while that from the lungs is only one pound. Much of the exhalation from the skin consists of watery vapor, but it also contains carbonic acid, with some other elements injurious to the lungs. The excretions of the liver also afford the lungs important aid in purifying the blood from carbonaceous matter, and imperfect performance of its functions is sometimes a cause of pulmonary disease. The action of the kidneys is of importance, as well as that of the skin and liver, and is indispensable to that pure state of the blood which the health of the lungs requires. It is also necessary that the blood should abound with highly nutritive elements. Persons who are deficient in the red blood-discs, or in the nutritious portions of the blood, are exceedingly liable to scrofulous and tubercular diseases—to consumption, and to the acute diseases of the respiratory organs. The symptoms that indicate that low state of the blood, so often the forerunner of fatal disease of the respiratory organs, are pearly whiteness of the sclerotic coat of the eye, a pale countenance, with or without a flushed cheek, and habitual coldness of the extremities.

519. The maintenance of animal heat is the most important and the most trying work of the lungs, in all temperate climates; since they are almost daily subjected to some vicissitude or change. The air inhaled, often varies several degrees in a few hours, and, in some instances, in a few minutes; the individual being at one moment in a room at summer heat, and the next in the open air at a temperature below zero. The delicate membrane that forms the six hundred millions of air cells in the human lungs, though admirably adapted to its office, is nevertheless subjected to a severe trial by the sudden changes of the temperature to which it is exposed. The amount of heat necessary to maintain a uniform temperature of the body is equally variable. No organ of the body enjoys so little uniformity in the performance of its functions as the lungs, and no other is so liable to disease. But it is equally true, that diseases of this most delicate organ diminish just in proportion as the temperature becomes more uniform—prevailing most during those months and in those localities where the weather is most variable. It may, therefore be regarded as a law of our organization, that the body should maintain as uniform a temperature as possible. In New England, during most of the year, we can live up to this law only by the use of artificial heat and clothing. Artificial heat, as produced by fires, is far more likely to be too high than too low for the welfare of all such as enjoy the means of procuring this comfort; because we cannot at all times be within doors, and the change, on going out, is proportionate to the degree of heat within. Clothing is, therefore, the most uniform and the most reliable protection against cold. The cause of the sensation of cold in the body, or any portion of it, is the conducting of the natural heat from the body to the surrounding medium. This takes place at all times when the temperature of the body is higher than that of the air. The object of clothing is not to create heat around the body, but to preserve that which is constantly forming. The best protection, therefore, is that kind of clothing which is the worst conductor of heat. Linen is a good conductor of heat, and may, therefore, be worn in warm weather, when we wish to reduce the temperature of the body, instead of maintaining it; but woolen and furs are very poor conductors of heat, and form the best articles of dress in cold weather.

520. The amount of clothing must depend upon the season of the year, the exposure, and the capacity of the individual for producing heat. In the young, and the aged, this faculty is at its lowest power, and they require more clothing than those in the middle and prime of life. Those who are subjected to an external exposure, require more than those who remain in-doors. The clothing should at all times be sufficient to preserve a comfortable warmth of the whole body during any ordinary exposure, and should be increased in proportion to the length and severity of the exposure. The extremities are the most exposed to the influence of cold, and require the best protection, though they are apparently the least cared for by a majority of persons. Any one who is accustomed to riding, may know, by experience, that the rest of the body is warm enough, so long as the hands and feet can be kept warm. Many persons bundle up the neck and throat to sweating point, while the extremities hardly enjoy a moderate protection. Such persons are the most likely to be afflicted with colds. The neck requires no more clothing than any other part; and the effect of shawls and fur collars is to invite an unusual supply of blood, which is driven away when the extra appliances are removed, giving rise to sudden chill and congestion, followed by inflammation. Garments that fit the person loosely, afford more warmth than such as are called "a snug fit;" for the reason that there will be a space of air left between the clothing and the body, through which the heat will be conducted from the body less rapidly, on the same principle that the warmth of a room is preserved by using double windows, with a stratum of air between them. Any one who has been caught out on a cold day, in a pair of tight boots, will need no argument to prove the correctness of this assertion.

521. The function of respiration has been described as consisting mainly in exposing the circulating fluid to the action of air. We regard a due supply of air as one of the conditions of respiration, and not a mere rule of Hygiene—a law of our existence, not a law of experience. That we consume a certain amount of air at each inspiration, and throw out a corresponding amount of carbonic acid, and that this carbonic acid is poisonous and destructive to human life, are facts of universal application (§ 103 and 104). Life cannot be sustained for any considerable time without air; nor can it be continued in carbonic acid gas. An obvious law follows—that every apartment we occupy, whether private or public, should be provided with some reliable means for conveying off the poisonous gas, and supplying the pure air. When we consider the delicate structure of the lungs, and the absolute necessity of efficient ventilation, we are not surprised, that from one-fourth to one-third of our race are scourged with lung diseases; since little or no care has been taken to obey this imperious law of animal existence. The dwellings of our

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§ 518. What condition of the blood is necessary to the health of the lungs?—What effect has action of the excretory organs on the blood?—What are the effects of a deficiency of nutritive matter in the blood? 519. What is said of the importance of maintaining a uniform temperature of the body?—How is this result to be effected?—What kinds of clothing are best adapted to this purpose, and why?

§ 520. What circumstances should regulate the amount of clothing?—Why do the extremities require protection?—Why is too much covering on the neck injurious?—Why do loose garments afford more warmth than tight ones? 521. What conditions and general facts in regard to respiration are stated?—What follows from these?—What is said of the usual deficiency of ventilation?—What is the proper mode of ventilating a room?

fathers—that hardy race which gave character to our republic—were constructed with reference to a liberal supply of this vital element. The massive chimney in the centre of the house, with its wide fireplaces, constituted a noble ventilator. At the present day, we have small chimneys, closed as perfectly as art can close them, by the use of air-tight stoves; excluding wholly the entrance of the pure air of heaven, and permitting only such gases to escape as have been formed by the burning fuel. In some instances, to place a more effectual prohibition on all possible ventilation, double windows and double doors are adopted—as if in imitation of the hybernating habits of the marmot (§ 116), who shuts himself into his den for the winter, and then gives himself up to the full influence of the narcotic poison exhaled from his own lungs. If a state of torpidity for the winter be the object aimed at by close chimneys, air-tight stoves, double windows, and double doors, then these contrivances are admirably adapted to the end proposed; but, for any other object of animal economy, their influence is highly pernicious. Every room should have an aperture for the entrance of pure air, and another near the top for the exit of the gases given off by respiration; and no family or community which neglects these conditions of health ought to expect exemption from disease.

522. The respiratory organs are liable to several distinct diseases which receive their names from the part affected. Thus we have pneumonia, or inflammation of the substance of the lungs; bronchitis, or inflammation of the air-tubes or bronchi; croup, laryngitis, &c.—all of which are acute diseases, and are usually caused by cold. The lungs are also subject to a disease of a chronic character, which is the cause of more deaths than any other known disease. This is called *Phthisis pulmonalis*, or pulmonary consumption. A disease so peculiar in its character, and so fatal to our race, seems worthy of a special description, though it is not our purpose to enter the lists with those who claim to have made some wonderful discovery, or to have found out some infallible remedy for its cure. Multitudes of such pretenders have arisen, but consumption still marches on to its fearful work of death, regardless of new theories and new systems of practice.

CONSUMPTION.

523. By consumption is meant the wasting of the body, from the effect of a disorganizing process in the lungs. It is induced by a variety of causes, the most important of which are hereditary predisposition, imperfect nutrition, and exposure to cold. The hereditary origin of consumption is established by the concurrent testimony of almost all writers on the subject; though it is believed by many, that the development of the disease may be prevented by proper care, or by removal to a climate where it does not prevail, at an early age, before the consumptive predisposition has commenced its work. Improper or insufficient nourishment—confinement in impure air—neglect of cleanliness—exhausting mental labor, or bodily fatigue—exposure to wet and cold—may interfere with the process of perfect nutrition of the body, or of some of its tissues, and predispose it to consumption (§ 188). Confirmation of this is observed in the lower animals. The lungs of cows confined in close stables in the city become tuberculous; and rabbits may be rendered so, by confinement in a close place, with bad food, for only a few weeks.

524. Consumption prevails more extensively in temperate than in hot or very cold climates. Particular localities, especially such as are exposed to damp and bleak winds, and sudden changes of temperature, are most favorable to its development; while, in places which enjoy the greatest uniformity of temperature, it prevails least. In New England, and the middle states, from one-fourth to one-third of all who survive the hazardous period of childhood, die of consumption. The period between the twentieth and thirtieth year appears to be that which is most liable to its attacks; and it is the conviction that many of those into whose hands this work will fall, are approaching that period of life, which has induced us to describe some of the symptoms of this fearful disease.

525. No disease with which we are acquainted is more insidious, or more deceptive, in its progress. In, perhaps, a majority of cases it becomes permanently seated and incurable, before its subject is made aware of its presence. In its first stages, it is seldom attended with much pain; or, with pain about the shoulders and chest, so trifling as to create no alarm, or to be referred to some other than the true cause. Nor is it always preceded by a cough. Tubercles, which may be regarded as the germs of the disease (§ 187), are often deposited before the cough commences, or while the cough is not sufficient to attract attention. The first symptom, however, which plainly indicates the true nature of the disease, is usually a dry, hacking cough, accompanied, or soon followed, by paleness of the countenance, and general debility. These steal on, with little apparent reason for apprehension, till tubercular deposition has so far taken place, that the disease runs a rapid course to a fatal termination. In other cases, the disease follows one or more severe colds, or inflammations of the lungs, or a fever accompanied by pectoral symptoms. In other cases still, the patients have been out of health, or in a debilitated state, before the commencement of any cough. In most cases, there is but little pain or suffering till the very last stages of the disease, and the unfortunate victim is seldom aware of its progress, except as it is learned by an increasing weakness and inability to endure accustomed labor or exercise. The subject of the disease, for the most part, is cheerful and full of hope, and unconscious of the destructive process that is wasting the vital powers. A kind of balance seems to be maintained between all the functions, that secures exemption from suffering. As the available portion of the lungs is diminished, the mass of blood that has to pass through them becomes less and less, and the wasting of the body and the failing of the strength seem to keep pace with the decay of the lungs. Thus the descent is easy, and the parting of the last filament of life very gentle.

526. Again and again has the discovery of a new and infallible remedy for consumption been announced, and almost every medical journal contains some account of the beneficial effects of some new course of treatment. Although a few instances have undoubtedly occurred where persons clearly marked as its victims have escaped, yet the great majority who have the disease once seated, fall before it, in spite of all that science or art can do. The only reliable course is in preventing or avoiding its grasp. Where strong predisposition exists, it can be avoided only by the most rigid observance of the laws of health, and an early removal to a climate where it does not prevail. Exemption can be purchased only by the most constant and persevering vigilance—not in the use of any panacea retailed at the shops, but in the avoidance of all debilitating causes; in the use of a generous and wholesome diet, and of all those means that invigorate and nourish the body.

HYGIENE OF THE DIGESTIVE ORGANS.

527. The function of the digestive organs (CHAP. V.) is to prepare the appropriate elements for the nutrition and growth of the body. The food of man, for the most part, undergoes some process of cooking, and then of mechanical sub-division, before it is received into the digestive apparatus. The first process of digestion consists in its further mechanical subdivision by chewing, or mastication. In the act of mastication, it becomes mixed with saliva, the natural secretion of the glands of the mouth. The solubility of the food is influenced, to a great extent, by the perfection of this process. If it is thoroughly mingled with the saliva, the second process is performed with more facility; but if the food is swallowed very rapidly, insalivation is imperfectly performed, and the process of digestion is more difficult. Americans, it is said by foreign writers, eat faster, if not more, than any other nation. This is unquestionably true of most of those persons who eat at hotels and boarding-houses, and who are engaged in active employments. The excitement of business impels men to hurry through their meals in the least possible amount of time, just as though time spent at the table was lost or wasted to no good purpose. In private families, and by men not devoted to some absorbing mercantile occupation, there is a more reasonable time devoted to supply the body with the nutriment it requires. Men who allow themselves but fifteen minutes at the dinner table, must expect to make a liberal allowance annually for the services of a physician; or if they should chance, by reason of a strong constitution, to escape for a few years, they may rest assured that their digestive organs will ultimately demand back, with interest, too, every hour they have been cheated out of at meals. Dyspepsia or indigestion will sooner or later follow

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§ 522. Mention some of the diseases to which the lungs are liable.—What is said of Consumption? 523. What are some of the causes of Consumption? 524. In what countries and localities, and at what age, does it most prevail? 525. Describe some of the symptoms of Consumption.

§ 526. What precautions should be taken to avoid this disease?—Is there any infallible medicine for its cure? 527. Give a summary of the processes of digestion.—What is said of rapid eating, and its consequences?

the habit of rapid eating. Thirty minutes is the shortest time that should ever be allowed for taking a full meal.

528. When the meal is finished, the stomach should remain undisturbed till the process of digestion is completed. The interval proper to be observed between the meals, depends on circumstances. In the adult, the healthy stomach requires from one to three or four hours for the process of digestion. Some kinds of food are digested much quicker than others; but hunger, or the desire for more food, is not usually experienced till some time after the stomach has disposed of its contents. If fresh food is received into the stomach before that of the previous meal has been digested, the process of digestion is disturbed. In this country, where the meals are composed of a mixed diet, from five to six hours is the proper interval to be observed. In children, all the functions are much more active, and they accordingly require nourishment more frequently. For children under seven years of age, about three hours is an average time of rest between the meals. Infants sometimes seem to need food as often as every two hours; while older children can often wait four, without inconvenience. Eating oftener than this is decidedly injurious.

529. The practice of allowing children fruit, candies, cake, &c., at any or at all hours, is always pernicious, and productive of evil. Such children are seldom healthy, and never pleasant and agreeable in their disposition. If they must be indulged in luxuries of this sort, let it be at regular hours. All the processes of digestion and absorption are carried on according to uniform systematic laws. Any interference with the processes of nature disturbs the whole economy. Irregular feeding not only disturbs and interferes with digestion, but it is a source of unpleasant and injurious irritation to the nervous system. We have often observed that clerks in grocery stores, who are allowed to be constantly nibbling at all sorts of articles, very soon become dyspeptic, or uneasy and restless in their habits, and ill-natured in their disposition. A druggist, also, who contracts the habit of tasting every prescription of medicine which he puts up, will very soon destroy the tone of his stomach, and will require a special prescription for himself. Children who need candy or sugar to keep them in good humor by day, will require an opiate to keep them asleep at night.

530. The true rule for the number and intervals of our meals, is "to proportion them to the real wants of the system as modified by age, sex, health, and manner of life, and as indicated by the true returns of appetite." The frequency with which different animals require their food bears a very close proportion to the frequency of their respiration; and, in the case of man, this proportion will also apply. Persons who take much exercise in the open air, and whose respiration is thereby accelerated, require food, and have a proper appetite for it, much more often than those who are indolent and sedentary. On the same principle, birds, whose respiration is very rapid (§ 92), will die of starvation in three days; while a serpent will live without food as many months. Carnivorous animals, such as the lion, tiger, cat, &c., thrive the best with only one meal a day, and their health will suffer if they are fed oftener. The law of health and of nature is, that the meals should be at regular intervals, and at about the same hour on each successive day. The number of the meals should be proportioned to the wants and circumstances of the individual.

531. Breakfast should always be at an early hour, and soon after rising. It is well known that the system is more susceptible of infection, miasma, and other causes of contagious or epidemic diseases, in the morning, than at any other hour of the day; unless, perhaps, when the system has been exhausted by fatigue (§ 182). Naval and military commanders have found, by experience, that, in unhealthy climates, their sailors and soldiers are much less susceptible to noxious influences after they have been fortified by a comfortable breakfast. In countries where ague prevails, the proportion of sick among those who are exposed before getting any thing to eat, is infinitely greater than among those who have breakfasted before exposure. In children, or in persons who are at all delicate, much exercise in the morning, before eating, produces exhaustion and languor, and often unfits the stomach for receiving and digesting food properly.

532. The advice sometimes given to invalids, to take a long walk or ride before breakfast, is not in accordance with the principles of Physiology, or the teachings of experience. Still, there are some persons who not only appear to suffer no injury from active exercise before breakfast, but are apparently benefited by it. Although many persons who have been accustomed to much active exercise in the morning, before eating, enjoy excellent health, yet it is in spite of the morning exercise, not in consequence of it. During sleep, at night, the absorbents become comparatively quiet and inactive, but commence their operations with renewed vigor as soon as the other powers are fairly awake, and an almost immediate demand for a fresh supply of nutriment is felt throughout the whole system. When this demand is not satisfied, prostration of the nervous energy of the digestive organs very soon follows, with sympathetic exhaustion of all the powers. We are acquainted with an enterprising farmer, possessed of what is sometimes called "an iron constitution," who has been the means of ruining the health of six sons in succession, by requiring them to work several hours before breakfast, under the delusive idea that in this way they would be strengthened and invigorated. There can be no objection, however, to early rising, provided it be followed by an early breakfast. Indeed, "early to bed and early to rise" is unquestionably the best practice for the preservation of health, under ordinary circumstances.

533. Dinner should be taken about six hours after breakfast. If the dinner hour is later, there should be a regular hour for luncheon; otherwise a luncheon should not be indulged in, except by children, and those who take active exercise in the open air. Children imperatively require some nourishment between the usual hours of meals, but it should invariably be taken at about the same hour every day. The dinner, as it is the principal meal, should occupy a longer time, and be followed by at least one hour's rest from any active exercise. The supper should be a light meal, taken at least two or more hours before retiring to bed, except in special cases. If a person has been obliged to undergo great exposure or severe labor in the evening, and has become truly hungry, some light nourishment is proper, even just before bed-time; since an empty stomach will sometimes prove a most disagreeable preventive of sleep. But the indulgence of the appetite in late suppers is one of the worst kinds of dissipation—a practice most pernicious to health, and a fruitful source of disease.

534. The kind of food proper for each individual must of necessity depend on as great a variety of circumstances as there are conditions of life. The climate, the season of the year, the age, the temperament, the occupation, and the habits of life—all require certain modifications of diet. If we examine the structure of the human body at different ages, and in different individuals, we shall observe marked difference in the relative proportions of the elements of which it is composed. In the man of mature years, the muscular system predominates, and the body is remarkable for the compactness of its fibre, which adapts it for feats of strength and activity. In the child, the fluids are most abundant, producing a full, soft, and rounded form. In advanced age, the soft tissues have greatly diminished, and the whole frame is dry and wasted. So, in different individuals of the same age, we observe dissimilarity of structure quite as conspicuous. One possesses large and powerful muscles, by which he is enabled to perform great physical labor; another has a "lean and hungry look," his muscles are smaller and weaker, and he pursues the sedentary life of a student; another has an excess of the lymphatic system, and is "fat and sleek-headed," and is only fitted for a life of comfort and ease. In short, there are almost as many different developments of the various tissues as there are individuals. The young, the aged—the laborer, the idler, the man of ease, and the student—each requires a diet adapted to his own peculiarities. The same is true of all the various grades and classes of men; and they can no more exchange diet with each other, than the young and the aged can exchange habits and feelings. Modifications of diet are not less required by residence in different climates. The inhabitants of the Polar regions live, to a great extent, upon that kind of food which is called calorific or heat-producing, such as animal fats and oils. On the other hand, those of the tropical regions abstain almost entirely from such arti-

§ 528. What is said of the proper intervals to be observed between the meals?—Why may children eat more often than adults? 529. What is said of allowing children to eat candies, &c., at all hours?—What are the effects of the habit of irregular eating?—What classes of persons are mentioned as liable to this habit? 530. What is the true rule for the frequency of our meals?—What proportion exists between the frequency of eating and of respiration?—What examples are given of this proportion? 531. When should breakfast be taken, and why?

§ 532. What is said of the propriety of severe exercise before breakfast?—Why do we demand nutriment on rising in the morning; and what are the consequences, if the demand be not satisfied? What other remarks are made on this subject? 533. What is said of dinner?—What of supper? 534. Is the same kind of diet adapted to every individual?—What peculiarities of age and temperament are mentioned, and what is the result of these peculiarities in regard to diet?—What is said of climate in this respect?

cles, and confine themselves to fruits and vegetables. It would be impossible to live, in Hindostan, on the seal-fat and whale-oil of the Greenlander; or, in Greenland, on the plantain and rice of the Hindoo. The same principle should govern, and does govern, to a great degree, the diet of the inhabitants of temperate countries. In winter, we eat larger quantities of meat than in summer; and in summer, more fruit and vegetables than in winter. No person could, in summer, indulge in the same diet which would be highly conducive to health in winter, without overloading the system with carbonaceous matter, and inducing congestive and inflammatory diseases.

535. The value of any particular article of food depends mainly on the facility with which it can be converted into the organized tissues of the body. In this process of assimilation, as it is called (§ 47), the nutriment undergoes digestion, absorption, and secretion. Of the facility with which different kinds of food are absorbed and secreted, we have but little practical knowledge. A variety of circumstances, however, affect the facility with which different articles of food are digested. Some kinds of food are naturally more difficult of digestion than others. This is especially the case with all oily or fatty substances. Tenderness of fibre renders the digestive process more easy; and, therefore, all those circumstances that affect the texture of flesh have an influence upon its digestibility. Violent muscular exertion, immediately previous to the death of the animal, renders the flesh more easy of digestion. The flesh of young animals, though more soluble and tender than that of the adult. is not so easily digested. Vegetables are generally more slowly digested than meat. Minute division facilitates digestion; hence, if food is perfectly masticated, the process of digestion will be more rapid than otherwise.

536. The art of cooking has as much to do with the digestibility of food as any circumstances belonging to the food itself, or the manner in which it is received into the stomach. The immediate object of cooking, as practiced by all civilized nations, is the gratification of the palate, the promotion of digestion being a secondary object. Cooking, for the most part, produces no chemical change in the constitution of food; it simply destroys its organization, and softens its texture. The process of *frying*, however, has an effect upon all animal fat or oils, which is exceedingly unfavorable to digestion. For the same reason, melted butter, buttered toast, butter-cakes, pastry, marrow and suet puddings, are all difficult of digestion, and "lie heavy on the stomach," as it is termed. Butter, and all fat substances, if used as food, should not be subjected to any process by which they become melted and their fixed oils set free. The whole process of pastry-cooking is at war with digestion. Articles of food that are naturally easy of digestion, become the most obnoxious to the digestive organs, by being compounded together. Thus eggs, fresh butter, bread, and sugar, are each very wholesome, and readily digested, when eaten separately; but when the eggs and butter are combined with the flour and sugar, to form cake, the compound may almost defy the powers of the stomach. Eggs, too, when slightly boiled, will not offend the most delicate stomachs; but, when fried hard in animal fat or butter, they are exceedingly difficult of digestion by the most vigorous. All compound food, or such as is formed by cooking several simple articles of diet in combination, is found more or less indigestible, according to the richness of the compound.

DIET OF CHILDREN.

537. We have already seen that the kind of food proper for each individual depends on as great a variety of circumstances as there are conditions of life. No specifications of diet can, therefore, be made applicable to every person. There should, however, be a marked difference between the diet of children and that of adults. Previous to dentition, the only diet proper for the infant is such as nature has provided—the mother's milk. When the young infant must be deprived of this provision for its wants, through inability or disinclination of the mother, a very close approximation to its natural diet may be made from the top of cow's milk that has stood two or three hours, combined with two parts of water and a small quantity of sugar. This mixture contains the same chemical elements, in nearly the same proportions, as the mother's milk. It is found to be a very safe and wholesome diet for the young infant. No other diet has been so fully authorized, either by chemical analysis, or by the observations of experience. This, or the mother's milk, is the only food that should be allowed previous to dentition; and a vast amount of infantile suffering would be saved by its rigid adoption. When the teeth begin to appear, something more is required. Farinaceous food, or such as is prepared from wheat, rice, &c., may be allowed in small quantities at first, and increased according to the child's wants. Whatever is given, should be well cooked, and not used on the same day that it is taken from the oven. The character of the food should be as uniform as possible, variety injuring rather than promoting health. Up to the appearance of the second teeth—usually about the sixth or seventh year—milk should constitute an important portion of the diet. Pastry of all kinds should be discarded. Meat is seldom required under four years of age, and should not be used freely under seven. It is more stimulating than other food, and is the cause of too much nervous excitement. Slender and feeble children sometimes require it at an earlier age. But most children enjoy better health, and are less liable to disease, without meat, unless it be given in small quantities. After the child is weaned, gruel, arrow-root, bread, crackers, rice, wheaten-grits, farina, &c., may be allowed, with a small quantity of sugar. Meat, when permitted, should not be used, except at dinner.

538. A great evil in the treatment of children, is over-feeding. In the infant, this is a most serious evil, and one that is productive of much suffering; giving rise to colic, bowel complaints, nervous irritability, and convulsions. Too often, the young infant is laid on its back, in the nurse's lap, and then compelled to swallow, to avoid choking, until it is literally running-over-full, and cries, from the pain caused by distention of the stomach. Again and again is this inhuman process repeated, whenever the unfortunate victim gives expression to its sufferings in cries. Nature has ordained that the food of the infant should be received very slowly from the breast, and that only during the will of the child. Artificial feeding is most perfect, when it imitates nature. The food should be plain and nourishing, and should be administered at regular intervals, and at nearly the same hours daily, none being allowed at other times. The food should also be administered gradually, and the child educated to eat slowly, and masticate its food thoroughly. If the food is taken moderately, and at the will of the child, there will be but little danger of over-feeding, unless it is tempted with choice bits, after the appetite is satisfied with the regular meal. During the cold season, sugar is a very useful article of diet, and may be allowed freely with other food, though it is not easily digested when taken alone. Candies are injurious; mainly because they are eaten at irregular hours, upon an empty stomach, or upon food that is in process of digestion. Candy, if eaten at all, should be rather in connexion with other food, or immediately after, as dessert. Used properly, sugar, in its various forms, serves a very important purpose in furnishing carbon to maintain animal heat. But when taken alone, or in rich cakes, it is exceedingly difficult of digestion, and is as injurious as it is useful when properly administered.

539. During the warm season, vegetables and fruit may be made the means of great mischief, or of great good. Perfectly ripe fruits and vegetables are highly useful, and well adapted to the wants of the system at this season of the year. Yet they may become a most prolific source of disease. So frequently is this kind of food a cause of bowel complaints, that most physicians discard it wholly from the diet of children, and some prohibit its use to adults. Vegetables and early fruit that have been long exposed in a malarious or filthy market, or in transportation, are unquestionably dangerous articles of food for all persons. But the injurious consequences that follow the use of ripe and wholesome vegetables and fruit, are, in almost all cases, caused by their improper or excessive use. Children require proportionately less of these articles than adults; and those who have not their full set of teeth, should be sparingly indulged in them during warm weather. Vegetables and fruit are to be regarded as safe only when used as an accompaniment to other food. They are not adapted to meet all the wants of the system, and therefore should not constitute a full meal at any time. Most persons, in the country, who suffer from their use, either eat them to excess, or as an indulgence of the palate, at irregular hours. Children are remarkably fond of fruit, as

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§ 535. What circumstances affect facility of digestion? 536. What is said of cooking as affecting the digestibility of food?—What articles are mentioned as difficult of digestion?—How should fat substances be used?—What is said of pastry-cooking, and of the impropriety of artificial compounds for diet? 537. What is the proper food of infants previous to dentition?—How may this natural food be imitated?—When the teeth begin to appear, what is the proper diet?—What rules are given in regard to eating meat?

§ 538. What is said of over-feeding children?—What rules are given on this subject?—What is said of eating sugar? 539. What is said of vegetables and fruit?—What circumstances render these injurious?—What rules are given for their use?

well as of sugar, and there seems to be in their constitution some inherent demand for these articles. No part of their diet apparently conduces more to their health and happiness, when they are allowed at proper times and as a portion of their daily food. But children are so prone to excessive indulgence in the various kinds of fruit, that great caution is necessary to prevent the most serious evils. When the quantity eaten is too great, or is imperfectly masticated, fruits are exceedingly liable to prove injurious, on account of their disposition to undergo an acetic fermentation in the digestive organs. By this means the very worst forms of disease of the bowels are often induced.

DIET OF ADULTS.

540. The same general rules should be observed by adults as have been laid down for children, though a much wider range of diet is allowed. Those whose habits of life lead them to take much active exercise, require a very liberal allowance of animal food; and those who labor out of doors, require more than those employed in shops. Merchants and tradesmen require less; and students, or men of sedentary habits, the least of all. Adults are injured by eating at irregular hours, by eating too fast and too much, by indulging in a a great variety of dishes that pamper the appetite to excess, and by food too rich and hearty for easy digestion. The art of cookery, when confined to its legitimate end, is highly useful; but it is a most mischievous and dangerous art, when it lends its service to the compounding of the fashionable lobster-salads, turtle-soups, rich cakes, &c. We have already alluded to the impropriety of late suppers. It would seem that no man of reflection, who has experienced one of those restless nights which follow a late supper, would need to be reminded that habitual indulgence in this practice wears out and deranges his most important organs, and that he is, in fact, guilty of a slow suicide. Perhaps no class of men are more reckless in their habits of eating than the students and clergymen of this country. Not that this class of persons are preëminently intemperate in their indulgence of appetite, when compared with other men, but the amount of exercise and physical exertion to which they are accustomed is generally much less than that of most other men; and, therefore, the quantity of their food greatly exceeds the wants of their system. All persons who take but little exercise, should refrain from rich and hearty food of every description. Meat may and should be eaten, but it should be mostly lean, free from rich gravies, and in small quantities. Animal substances become indigestible, by being either too much or too little cooked; vegetables, chiefly by being cooked too little. Fried and stewed dishes—very highly seasoned articles—fish cooked in animal fat—are all prejudicial to the digestive organs. All condiments, unless in small quantities, are hurtful; salt, vinegar, and lemon-juice, are the most wholesome, under all circumstances. Baked pastry, pies, and tarts, and the boiled dough of puddings, are difficult of digestion. A great variety of fruits, at the same meal, is also injurious. All preserved and stimulating articles of dessert, nuts, melons, raisins, &c., are always more or less indigestible. Excessive indulgence in fluids of any kind weakens the power of the gastric juice, and renders digestion more difficult.

DISEASES OF THE DIGESTIVE ORGANS.

541. The digestive organs are subject to numerous diseases. Among these are several of an acute and inflammatory nature, such as gastritis and enteritis, or inflammation of the mucous membrane of the stomach and bowels; while others are of a slow or chronic character. The acute diseases are usually caused by sudden exposure to cold, and suppression of the excretions of the skin; by atmospheric influences, or by improper diet. To this class of diseases children are peculiarly subject. Adults suffer principally from slow or chronic disease, and from that disordered condition of the organs of digestion usually called dyspepsia. The consequence of improper care of these organs often shows itself in other organs or tissues. Not unfrequently, the powers of the digestive organs become impaired only so far, at first, as to interfere with the perfect nutrition of other parts. The respiratory organs, the nervous or muscular systems, will become thereby weakened, and the whole body debilitated; so that the first excess or irregularity, or the first exposure to cold, develops disease either in these or in some other part of the body. Thus, indulgence in too great a variety of meats, in highly-seasoned dishes, rich soups or rich sauces; in vinous or spirituous liquors; over-loads or over-excites the stomach, and disposes it, as well as the brain and the bowels, to inflammation, or to functional and organic disease. If the digestive organs do not themselves become diseased or enfeebled, under a course of high living, general plethora is often induced, predisposing to inflammation in early life, and to gout and apoplexy at a later period.

542. On the other hand, an insufficient, meagre, innutritious diet, composed of food of a watery consistence, predisposes to disease, because it does not afford a sufficient amount of nutrition to maintain the powers of life. It is also a source of irritation to the stomach and bowels, and may give rise to typhoid fever, dysentery, cutaneous complaints, worms, consumption, and scrofula. The digestive organs often hold out for a long time against the most perverse indulgence in all that is pernicious and unwholesome in diet, and then suddenly give way, rarely to recover their original health, tone, and vigor. He who has once wasted the powers of his digestive organs, and become a dyspeptic, must remain as great a slave to his impaired powers of digestion, as he has been to his appetite, and must ever after continue as anxious that he may so eat as to live, as he was, before, to live for the sake of eating. Next to improper diet, the improper use of purgative medicines exerts an influence to weaken and impair the digestive organs. The taking of medicine for this purpose should therefore be regarded as an evil, to be avoided, if possible. Pills and powders may relieve the over-loaded bowels for the moment; but the longer their use is continued, the more obstinate becomes the disease which they are intended to remedy.

HYGIENE OF THE NERVOUS SYSTEM.

543. The brain, which is the organ of the mind and the centre of the nervous system, is united with the strongest sympathy to every part of the body, by means of the spinal cord and the cerebro-spinal nerves. By a law of our organization, the nervous system is thus made to participate in all that affects any portion of the body, and to take cognizance of any destructive process that may be occasioned either by mechanical injury or by disease of any organ or tissue. The health of the nervous system is, therefore, dependent upon that of the other organs, and is made sensitive to every interruption in the harmony of the whole. It is impossible to preserve this system in its full power and vigor while the body, or any portion of it, is wasted by disease. The nervous system also participates in all the various changes which occur to the body in a state of health. Appetite, hunger, thirst, fatigue and relaxation, labor and rest, variations of temperature and excesses of heat and cold, all produce upon it their appropriate impressions. Since the mind is the exponent of all the impressions made on the brain, it follows that the phenomena of thought must, to a great extent, receive their character from physical causes operating through the nerves which are distributed in the various organs.

544. The sympathy between the brain and the organs of digestion is remarkable. The stomach, probably, has a greater influence upon the passions, habits, and morals of men, than any other part of the body. The state of the stomach may be pretty correctly ascertained by observing that of the passions and feelings; and by the diet adopted, and the consequent condition of the stomach, may be learned the moral character and intellectual habits of the individual. Those who eat large quantities of hearty food become either morose and irritable, or dull and stupid. They are unable to apply themselves to intellectual pursuits with efficiency and success, or to sprightly and active physical exertion. Men who give themselves up to the gratification of the appetite, seldom practice self-denial in any thing else. The will seems to lose its control, and mismanagement of the stomach is followed by all the evil effects which spring from abandonment to any other vicious propensity. Indeed, the study of the stomach has been said to be the study of morality. He who controls his appetite will possess self-control in other respects; and the loss of self-control is sure to follow the unrestrained indulgence of the appetite.

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§540. What rules are given for the diet of adults?—What articles are mentioned as injurious? 541. Mention some of the diseases of the organs of digestion, and their causes? —What is said of the effects of high living?

§542. What are the effects of innutritious diet?—What is said of dyspepsia, and of the use of purgative medicines? 543. What is said of the connexion between the nervous system and all the organs of the body? 544. Describe the influence of the stomach upon the brain, and the habits and morals of man.

545. Upon the mind of the student, the influence of the digestive organs, through the nervous system, is most marked and peculiar. When he has eaten too much for the powers of his stomach, his thoughts seem weighed down by an incubus which they cannot throw off. All power of vivid conception and expression is gone. He can neither think, nor write, nor speak, with his wonted ability. On the contrary, a light and simple diet allows the brain to perform its duties with ease and clearness. The mind becomes active, and the imagination elevated.

546. Nothing is more destructive in its effects than constant mental labor combined with too free indulgence in the pleasures of the table. No literary man can long sustain the joint operation of these excesses upon his health. The brain and the bowels soon become equally sluggish and equally impaired, and that dreadful train of nervous diseases ensues, the horrors of which too many have experienced. In these cases, the over-burthened stomach is often relieved by the ruinous practice of taking cathartic medicines—a mode of relief which only complicates the symptoms—until a pill, or a powder, becomes a necessary precursor to successful intellectual effort. Byron says of himself, "The thing that gives me the highest spirits is a dose of salts." It diminished, for a time, that irritability and congestion which his habits tended to perpetuate. In the end, however, as his biographer tells us, the practice of taking purgatives ruined his health, and was one of the chief causes of that weakened condition of his frame which rendered him unable successfully to cope with a disease by no means commonly fatal in its termination. In his case, as in that of all literary men, the first causes of the necessity of taking purgatives should have been avoided.

547. The effects upon the mind, of that derangement of the liver so often the consequence of improper eating and drinking, are somewhat peculiar. When this important organ becomes inactive or diseased, and unable properly to perform its functions, all the powers become oppressed with a melancholy—dark, despairing, and constant. Intellectual exertion is impossible; the brain becomes confused; the attention cannot be fixed; the pleasure and the desire of life vanish; the moral susceptibilities are blunted, and the victim becomes a prey to wild and desperate fancies. The disordered brain reacts upon the muscles, and an aversion to physical exercise ensues, the effect of which is to perpetuate and confirm the mental malady. The only remedies which can minister to a mind thus diseased, are to be found in a total abandonment of the practices which have caused it, and the adoption of a systematic mode of diet and exercise.

548. The muscles sustain a peculiar and important relation to the nervous system. The capacity of the brain for the endurance of mental labor depends, to a great degree, upon the proper exercise of the muscular powers. When the muscles become weak and flabby, through inaction, the brain becomes correspondingly incapable of vigorous effort, and the nerves lose their firmness and tone. On the contrary, a well-developed muscular system, hardened by exercise, is seldom accompanied by any form of nervous disease.

549. From the foregoing considerations, and from many others which might be mentioned, it is evident that one of the most important results to be secured in the education of the young, as well as in the occupations, of those of mature years, is perfect physical health. The necessity of bodily health to successful intellectual effort, will be readily acknowledged by any person who devotes attention to the subject; and yet our schools, academies, colleges, and all the educated classes of society, furnish most melancholy demonstrations that the body is too often lost sight of in the cultivation of the mind. A brilliant genius, or a highly cultivated intellect, joined to a debilitated body, renders its possessor rather an object of pity than of envy. The noblest powers are chained down by physical weakness. In the sacred profession, particularly, many of the finest intellects are lost to their possessors and to the world, because there is not physical strength to sustain the mind in its labors, and, consequently, "a train of nervous affections and perverted imaginations, as permanent as life, and less supportable than death itself, take possession of the invalid student."

550. In the opposite sex, the consequences to the nervous system, of neglecting physical health, are still more melancholy. The young female of twelve or fourteen, with her beautiful figure, rosy cheeks, sparkling eyes, and airy step, presents a picture full of life and happiness, at once attractive and lovely. The mind, too, possesses the same healthful sprightliness and vigor. At about this age, the lively motions of the body and limbs must be restrained, and the hypocrisy of what is called "woman-like deportment" is made to conceal every impulse of life and vivacity. The disposition for activity is controlled, if not destroyed, by an artificial system of dress and manners. Confinement soon begets a frivolous disposition, and a nervous irritability. The muscles become weak and flabby, and unable to sustain the bony frame, and the bones themselves are softened in structure. Permanent deformity of figure soon follows; digestion and nutrition are imperfectly performed. At the youthful age of twenty, three-fourths of what are called well-educated ladies have lost the freshness and beauty of youth—have become pale, slender, and unhealthy, and for ever unfitted for the high duties of life.

551. While the physical powers are thus fearfully neglected, little regard is had to the capacity of the nervous system to endure mental labor. The brain must become fatigued, exhausted, and debilitated, just in proportion to its inability to endure the amount of mental effort imposed on it. Therefore, to preserve a sound mind in a sound body, the habits of both must be in accordance with the laws growing out of their mysterious union. In all exercise of the intellectual powers, there must be an abundant nutrition of the nervous substance, and a due supply of highly oxygenated and purified blood. Hence intellectual effort is as truly exhausting to the physical powers as any kind of physical labor, and there is the same demand for rest and relaxation. When the mind is exercised, there is an increased flow of blood to the brain. This is very apparent, from the fullness of all the blood-vessels about the head, when the passions are excited. In anger, for instance, the little vessels of the eyes become so disturbed as to be blood-shot, as it is called, and the blood-vessels of the face are so full as to give a fiery red appearance to the whole countenance. In long-continued, close application of the mind, the extremities have a constant tendency to become unusually cold, while there is an increased temperature of the head.

552. The brain of a student as imperatively demands rest as the muscles of a laborer. The muscles in the arm of a smith, for instance, after a certain amount of labor, become fatigued, and then grow weaker, if labor is continued, till the arm is comparatively powerless. Just so when the will has wearied the brain in close study, an indescribable confusion comes over the mind, that forbids all further effort till rest is taken. The muscles and the brain both gain strength by alternate labor and rest, when they are properly nourished; but the kind of rest required by the one, is very different from that required by the other. To refer to the smith again: the instant he lays down his hammer, his muscles begin to take their rest. Not so with the brain of a student. The mind we regard as constantly active, at least during the wakeful hours. The student may, therefore, lay down his pen, or his book, and even leave his study, and yet his brain may find no rest. It may continue to act on the same subject for hours, while the individual is apparently engaged in very different occupations. Thus, men who become intensely interested in any particular study, exhaust their powers with most surprising rapidity.

553. To receive rest for the brain, the mind must cease to act on the subject that induced the fatigue. Either some new subject must engage the attention, or the mind must be allowed to contemplate a variety of new objects. New scenes must be presented, and new trains of thought awakened. A vast amount of intellectual imbecility and physical weakness, disease, and suffering, has been caused by a disregard of these principles. We believe the number of students who injure themselves by active study, however, is very small, compared with those who are injured by the want of proper rest and relaxation for the brain. In the intervals of study, the mind is allowed to follow the same trains of thought that induced the fatigue. A student of geometry, for instance, who leaves his study for a walk, and occupies his mind in revolving over the proposition he has just demonstrated, will be sure to return with a brain as much fatigued

§ 545. How is the mind of the student affected by the digestive organs? 546. What are the effects of mental labor combined with excess in the indulgence of the appetite?—What is said of the practice of taking purgatives for relief?—What instance is mentioned of the evil consequences of this practice? 547. What are the effects of a derangement of the liver upon the mind? 548. What is said of the relation of the muscles to the nervous system? 549. What conclusions are drawn from these considerations?—What remarks are made on this subject?

§ 550. What are the consequences of neglecting physical health among females? 551, 552. What is said of the necessity of rest and relaxation to the brain? 553. In what manner should the brain be rested, and what are the consequences of too constant mental labor?

as before. His ability for continued study is much less than that of one who spends the same length of time in active, vigorous exercise, which calls the mind to an entirely new and different field of thought. Daily exercise that interests the mind, and calls it off from its accustomed labors, is indispensable to the mental and bodily health of all persons who devote themselves to study, and it is unquestionably the true way to think. The best thinkers are those who possess the power of exerting their brains with the most energy for a limited period of time, and who then take liberal relaxation. The brain thereby exercises the power of prompt, energetic action; and when it acts, it is to some purpose. Those who keep the brain constantly at work, either become dull and lazy thinkers, or are prematurely worn out.

554. The capacity for mental labor varies exceedingly at different periods of life, and education should be conducted with direct reference to this fact. In children, the brain is considerably larger, in proportion to the body, than in adults. The nervous system is correspondingly more active. All the animal functions are performed with more activity. Respiration, circulation, digestion, take place with greater rapidity. With growing years, all these processes become slower, while there is a constant increase of the ability for patient, persevering application of both mind and body. The powers of the child seem adapted to rapid transition from one object to another. His mind is constantly on the alert for something new—something to see, handle, and taste. All his senses are acutely alive to the investigation of the properties of the various objects that come within his grasp; and it really seems as though his nature felt that life was too short for the great work of investigating the external world. Continued application to a particular object is wholly incompatible with his natural impulses. Fatigue very soon ensues, when this is attempted. It is as impossible to confine the mind of a child to a particular object, for any great length of time, as it is to teach its body to remain in one position.

555. The brain of a child is totally unfit for that mental exertion to which it is often forced or excited by many parents who allow themselves to be flattered with the developments of precocious intellect. Fatal disease is thus frequently induced, and, where death does not follow, idiocy, or intellectual imbecility, nips the bud of opening intellect, and disappoints all the flattering prospects of future greatness. Nothing but actual disease should make a parent more anxious for the welfare of a child, than the rapid development of a brilliant mind. So true is it that what are called "*bright children*" die young, that we often hear it said of such a child, "He has not long to live." In children of this character, the brain and nervous system are already too fully developed for the other powers. In children, generally, the peculiar activity of the brain seems given for the purpose of developing the physical powers with greater rapidity, and not so much for the growth of the mind. The education of the physical powers should be regarded as of the first importance. But, with those that are naturally precocious in intellect, special care should be taken to promote the vigor of the body, and restrain the exercise of the mind till the physical powers shall become strong and healthy, rather than to fan the flame already kindled till it consumes the citadel of life.

556. The practice of confining young children at school almost as soon as they can leave the nursery, is wholly incompatible with their nature, and at war with their best good. In some, it is the cause of disease and premature death; in others, it results in exhaustion of the nervous power, and consequent bodily or mental imbecility; and in the remaining and larger portion, it creates a dislike of the school-room, and a disgust with study which greatly retards their progress in subsequent years. Six years for a majority of children, and eight for those whose nervous system is naturally predominant, is the youngest age at which the confinement of the school-room, or the excitement of study, can be borne with impunity. Children younger than this are not formed for the monotony and fixedness that are held indispensable to the order of a good school. The brain is fatigued with the unnatural duties imposed upon it, the muscles become impatient of the restraint, and the very bones are intolerant of their confined positions. We can hardly conceive of a practice more at war with the natural impulses of a sprightly, active child, or more wicked in its physical and mental influence, than confinement to the imperative stillness of school, for from one to three hours each half-day, at an age when every instinct is impatient for change and action, and it is no matter of wonder that three-fourths of the children from four to eight years of age are unhappy and discontented at school, and but little profited by instruction, while the other fourth are seriously injured by the improper labor imposed on the brain.

557. While at school, special care should be observed not to demand of the brain more than it is able to perform, and the field of knowledge to the young should always be made pleasant and attractive. Not that the rugged ascent should be levelled down, nor should they always be kept in the plane at the foot of the hill of science. Vigorous, persevering labor is indispensable to the full development of the powers of the mind, and it is safe and proper when rightly applied. We believe there is an instinctive love of knowledge in all minds, but every mind has a capacity and a track of its own. Within its own capacity, and in its own sphere of action, the mind finds healthful pleasure in surmounting difficulties, just as healthful physical labor imparts vigor to the body, and gives new zest and new relish to the appetite. The great secret of safe and successful teaching lies in the adaptation of instruction to the capacity of the young, and in not requiring more than the brain is able to perform; though there is no necessity that knowledge should be diluted and simplified till it is reduced to dialogues and pictures. The whole course of teaching should have for its object to lead out the mind to think for itself in quick sympathy with those who teach.

558. The great fault of most teaching, is an abortive attempt to drive the mind through a monotonous routine of tasks and verbal drudgery, without any reference to the scholar's power of comprehension and understanding. The brain is thus wearied and jaded, like a pack-horse beneath his burden, and all to no purpose. The mind either has no relish for such labor, and is disgusted, or turned against it, or all the energies are ultimately crushed beneath its unnatural load. Such, to a great extent, is the influence of imposing long lessons, in which the mind cannot possibly perceive any good, nor feel any interest more than would be experienced in the reading of a dictionary. To be sure, a child, by extraordinary exertion, will occasionally commit to memory perfectly a long column of words, and their definitions, when it cannot take the least interest in the task, while the majority of minds will be fatigued and disgusted. But the drawing on the black board of a map of a particular country, and a description of its soil, its productions, its inhabitants, its mountains, and rivers, are all matters of pleasant and useful knowledge. So the description of the heart, and its action in man and in the lower orders of animals, is something the mind can grasp and retain with pleasure. The reflective and perceptive faculties in the young are most active, and most proper to be cultivated. The mind of a child is seldom so stupid as not to be interested in something it can perceive and reflect on or think about. Such objects only should be presented to the mind as it is capable of learning. Perfection should be the rule of all progress. A single truth, remembered and understood, strengthens the mind and develops the powers of the brain, while a mass of learning half understood and half remembered, begets confusion of the mind, and fatigues the brain.

559. The nervous system of students of all ages is too often made to suffer, in order to gratify the teacher's love of display. The success of the school and the merits of the teacher are thought to depend on the amount of studies pursued in a given time. Study is added to study to fill up every hour, and in some instances every minute, till the whole nervous system begins to suffer with feverish excitement. Under this process of forced development, the bodily health is gradually undermined, and the brain exhausted and enfeebled. Young ladies are made to suffer from this system more than the other sex. At boarding-school they are allowed less exercise, and are required to pursue a larger number of studies. We have known instances in which girls have been taxed with six or eight different studies—more than double the number that any ordinary mind can pursue with safety and profit. It is well known, that the mind for a time seems rested by changing from one study to another; but, in point of fact, it is no rest for the nervous system: it is only adding a new stimulus to excite further exhaustion of the brain. A great variety of studies is therefore the most sure way that can be imagined of literally using up and spending the greatest possible amount of ner-

§ 554. What is said of the activity of the brain and nervous system of children?—555. What is said of the evil of unduly stimulating the minds of children? 556. What errors are pointed out in the usual system of educating children?

§ 557, 558. What rules are given for the proper management of the intellectual powers of children? 559. What is said of the evils of undertaking too great a number of studies at once?

vous power. Those teachers who attempt in this way to stimulate the minds of their pupils to extraordinary exertion, incur a most fearful responsibility of sacrificing mental vigor, health, and life itself, to a wicked ambition for imparting to them a vast amount of knowledge in a very little time. As a natural result of this system, young ladies who "finish their education," as the process is called, at the popular schools, return to their friends with impaired health, to sink into a premature grave, or with intellectual inactivity, to drag out a miserable existence, scarcely more tolerable than death itself.

560. If sufficient vigor of constitution is retained to avoid the immediate consequences of the attempt to crowd the mind, a reäction ensues, in which the body for a time asserts its rights to be cared for, and the mind, as by a law of nature, seeks quiet and rest. Hence, many young ladies literally finish their education at the boarding-school, and never after manifest a disposition for study. For the same reason, children who are precocious or remarkably forward while young, seldom realize in after-life the brilliant promises of childhood. Early or rapid intellectual development is, therefore, to be feared and avoided, rather than encouraged. And all those means that are resorted to, for the purpose of stimulating to still greater efforts those whose brains are already too active for the health of their bodies, are productive of much more evil than good. Extraordinary appeals to the pride and ambition of youth to exceed their competitors, may make brilliant scholars at the recitation, and give an institution an excellent name, but they rob the world of the usefulness of many of the choicest spirits. "The laurel crown is commonly for the dead;" if not corporeally, yet mentally. Those who attain the highest honors of their *Alma Mater*, are generally diseased men. "Like phosphorescent insects, their brilliance lasts but a little while, and is at its height when on the point of being extinguished for ever; or, having reached the object of their ambition by concentrating their energies, an intellectual palsy too often succeeds, and their bodies partake of the trembling feebleness. The impression of undue determination remains upon the brain, which continues subservient to the ambitious will, until its structure and its functions fail together. The early effort opened a fountain of energy abruptly. It cannot be perennial; the waste is more rapid than the supply, and like water bursting from its channel, it must run to waste until violence ends in exhaustion."

561. The present condition of many of the educated portion of society in our country, admonishes us of the vast importance of seeking some remedy against the effects of literary pursuits and sedentary habits on the physical and mental powers. Professional men, and students of both sexes, are constantly "*breaking down*," while yet in the morning of life. Many of the first class of professional men are obliged to suspend their labors for a foreign tour, in order to recruit their worn-out bodies, and to rest awhile from their cerebral occupations, while many others are under the necessity of withdrawing entirely from the field of literary pursuits, and of seeking some employment in which less is required of the nervous system. In various ways, for the want of sufficient physical health, the services of educated mind, to a most melancholy extent, are lost to the interests of education, the church, and our country.

562. In regard to the causes of so much failure of health among the educated, there can be but one opinion. The muscular system is weakened for the want of proper exercise and nourishment, and the nervous system is exhausted by excessive application. It is often difficult to determine, however, whether more students lose their health from too much mental labor, or for the want of sufficient bodily exercise. We are of the opinion, upon the whole, that notwithstanding both causes may operate conjointly, a majority of those who have the credit of "*breaking down*" from hard study, do not deserve it. Their health is sacrificed not to science, but to bodily indolence. Nothing is more natural than for inactivity to beget an instinctive dread of active exercise. A man with a fractured leg, who is exceedingly impatient and restive under the confinement of the first week, will come to dislike exertion in a few more weeks, and will have but little disposition to move about when he has permission to do so. So the student, who has neglected exercise till all his powers are suffering for the want of it, will undertake with reluctance a walk of a mile or two, which would once have given him much pleasure. Fatigue, after a short walk, becomes the prominent feeling, and he returns with the idea that exercise, since it brings on fatigue, is not only useless, but hurtful to him. In the mean time, he finds his relish for food and his ability for study gradually diminish, till he is ultimately obliged to abandon his books for a time, and perhaps spends the remainder of his days as a "literary dyspeptic," under the honor of having ruined himself by *hard study*.

563. Of all broken-down constitutions, that of the literary invalid is the most difficult to repair. His is not the wreck of sudden violence, but a gradual insidious wasting of the basis and frame-work of his organization; and his is an existence of no common suffering. His physical power is gone, but his nervous system has lost none of the acuteness of its sensations. It is, in fact, more susceptible of impressions, more irritable, and more capable of suffering than before. Little occurrences annoy and disturb him, and he becomes irritated and vexed with every little mishap in the affairs of life. If his literary labors are not entirely neglected, he finds it exceedingly difficult to proceed with them. At times, he feels that his friends have deserted him, or have no sympathy for his misfortunes. The world has lost its attractions and its loveliness, and he would gladly exchange positions with the day-laborer in the street. Such, in brief, is the condition of most of those who have cultivated the mind and neglected the body.

564. Regular daily exercise of the muscles, and relaxation from mental effort, are the only sure means of avoiding these evils. So long as the vital laws of our organization remain in force, these are the imperative conditions on which men of sedentary habits may continue the enjoyment of health, and the vigorous exercise of their intellectual powers. All men are incapable of constant mental labor, and the necessity of rest and relaxation to the brain is as essential to its vigor as the supply of nutriment to the body. Without exercise, all animals lose their vigor, and become feeble and diseased. The kind of exercise proper for persons of sedentary habits, depends on a variety of circumstances that will be considered in connexion with the hygiene of the muscles.

565. The habitual use of stimulants of all kinds is decidedly injurious to the nervous system of the sedentary. Under their influence, the action of the brain is exalted above its natural standard, while it suffers an equal depression when the stimulant has spent its force. The natural normal action of the brain is most uniform, and most perfect, and its powers are correspondingly more enduring, when it acts spontaneously. Narcotics and stimulants, when used, are both prejudicial to the permanent vigor and health of the brain.

566. The fatal diseases of the nervous system are less numerous and less common than those of the respiratory and digestive organs. The brain and its membranes are each subject to inflammation, and to slow chronic disease. Acute disease of the spinal cord and its membranes seldom occurs, except from mechanical injury, while chronic affection of this portion is perhaps more common than in the cerebral part. The nerves are exceedingly liable to an affection called neuralgia, that is, pain of a nerve. The diseases of the brain are peculiarly insidious in their commencement, and are very liable to go on to a fatal termination, in spite of the most faithful efforts to stay their progress. The causes of cerebral disease are excessive mental employment, long protracted attention to one subject, over-exertion without requisite repose and relaxation, particular desires or passions, all depressing emotions of the mind, and great mental excitement.

567. That peculiar form of disease called neuralgia has become very common in our country. It may affect a particular nerve, or a particular set of nerves. The nerves of the head and face seem to suffer more severely and more frequently than any others. Neuralgia, when severe, is characterized by sharp, lancing, lacerating, or darting pains. In the whole catalogue of disease there is no suffering more intolerable or more to be dreaded, than an obstinate, long protracted neuralgia. It is induced by all those influences that have a tendency to depress the general health, such as residence in damp localities, exposures to sudden changes of temperature, and the habitual use of narcotics. It is the testimony of the best medical authorities, that wherever the habitual use of coffee and tobacco has increased, neuralgia becomes more prevalent. In many persons, the indulgence in two cups of coffee each morning for only two or three

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§ 260. What farther remarks are made on this subject? 561. What is said of the loss of health among professional men? 562. What is said in regard to the causes of this?

§ 563. What is said of the difficulty of repairing the broken-down constitution of a literary invalid? 564. What are the means of avoiding the evils arising from literary labor? 565—567. To what disease is the nervous system especially subject?—What are the symptoms and causes of neuralgia?

days, will induce severe neuralgia for a week. Persons of sedentary habits, and those whose nervous system is not fortified by active exercise in the open air, are most liable to this painful disease.

HYGIENE OF THE MUSCLES.

568. The muscles exercise a great influence upon the habits, condition, and actions of all animals. Nearly all the phenomena of life are made manifest through their operation; change of position, respiration, speaking, and labor of every sort, are all performed by the muscles. Our ability to undergo the duties of life depends on their health and efficient action. The strength of the muscles depends mainly on their use and the amount of nourishment received into the system. The muscles in the arm of a blacksmith are proverbial for their great size and strength, which are acquired by their alternate exercise and rest. When he changes his habits, and adopts a sedentary life, his muscles gradually diminish in size and strength. By muscular exercise, the flow of blood in the arteries and veins is increased, causing a more rapid deposition of the particles of nutritive matter. When muscular exertion is long continued, exhaustion ensues. Therefore, exercise and rest should be alternate; otherwise the loss of material will soon exceed the deposition of matter. The force with which muscles contract, depends on their size and condition, together with the energy of the brain, or the excitement at the time. Thus a man under temporary excitement, or in a fit of insanity, will perform feats of strength that he would be wholly incapable of, under any ordinary circumstances. By a certain restricted course of exercise and diet, very great muscular power may be acquired. Pugilists go through such a course, and acquire an unusual amount of strength thereby. In *training*, as it is called, for feats of strength, the diet consists mostly of plain beef and mutton, with bread or biscuit, spirits of all kinds being strictly prohibited. It is found, by experience, that this kind of diet, together with proper exercise, is best adapted to produce muscular strength in all persons.

569. Such is the dependence of the muscular and nervous systems on each other, that muscular exercise is indispensable to the healthy action of all the other powers. The practical importance of bodily exercise to health, is acknowledged by all who reflect on the subject, and yet it is almost as universally neglected among adults. Children, however, have only to be left to their own impulses, to find the means of taking abundant exercise. If not restrained and discouraged from doing so, they are sure to be found in the open street, court, or yard, acting out the impulses of their nature in frolicsome sports of some kind. Next to the demand in their nature for food and clothing, is the necessity for bodily exercise; and we believe it to be as imperative a duty, on the part of parents, to permit their children to enjoy the free use of the necessary means for healthful exercise, as to provide their food and raiment. Much of what is usually called mischief will thereby be avoided, without violating the laws of their nature. He who can look on the sports of childhood in an irritable, fault-finding spirit, and wish to restrain them to quiet inactivity, must either be destitute of common humanity or sadly ignorant of the process by which nature develops her powers.

570. The sports of youth are a necessary part of their nature, and the evils that grow out of them should be corrected in a generous spirit, and by kindly pointing out a better way. At all ages, children should be allowed to spend some portion of each day in the open air. Nothing but the most inclement weather should deprive them of this necessary condition of health. Whatever dangers may attend habitual exposure to the cold air, they are, in the end, less than those incident to the accidental exposure of a constitution made delicate by confinement. But their dress should always be sufficient to keep them comfortably warm, and so arranged as to allow of that free use of the limbs to which nature prompts, without impropriety.

571. Young ladies, students, and men of sedentary habits, are most liable to suffer for want of exercise. Young ladies, from twelve or fourteen to twenty years of age, suffer more than any other class from this cause. The fashions and customs of society oppose almost insuperable barriers to generous exercise at this most interesting age. Any thing that approximates to free action of the muscles of the limbs and body, is regarded as unlady-like "romping," and therefore very improper. The young lady of sixteen must observe, in all her movements, a woman-like grace and dignity, and must studiously avoid all feats of sprightliness, as unbecoming her sex. Until more liberal views prevail, in regard to the physical conduct of young ladies, we have no hope that our educated women will ever enjoy sufficient health to maintain their true position, as happy and useful members of society. Under the present system, they must for ever remain feeble, delicate, nervous, deformed, and diseased, making life an existence of suffering and trial, such as can be borne only by a woman's patience. The affluent are required, as by a law of caste, to spend most of their time in study or reading, or on needle-work, or some frivolous work of fancy, with no other exercise of the muscles; while those of the middle classes are above the servile labor of house-work, and resort to ill-ventilated manufactories, to breathe, over and over again, the air that is kept studiously confined from October to May: many of them enjoying no thorough ventilation for more than half of the year. It is no wonder that a majority of the female operatives lose their health in a few years. Humanity and the well-being of our race most imperatively demand a reform in these respects. We have often thought that the condition of those hardy girls who toil for their week's wages in our kitchens, is to be preferred to that of the sedentary, neuralgic, and deformed ladies of the more affluent circles. Notwithstanding the ignorant and reckless imprudence of the laboring classes, they certainly enjoy more of life, are less annoyed by its ills, and better fulfil its great ends, so far as physical health is concerned.

572. Perhaps there is no exercise more proper and beneficial to young females than walking in the open air. It should, however, be a free, unrestrained exertion of the powers of locomotion; and, in order to accomplish the utmost good, should have an object. If a walk be taken as a matter of duty, without enlisting the feelings and exciting the brain and nervous system, it loses half its value. Some object of interest, therefore, should be chosen to divert the mind. No better plan can be devised, for this purpose, than the adoption of a system for collecting specimens of natural history. The exercise, the calling out of the mind to the study of nature, and the specimens themselves, are all valuable. Plants, insects, birds, minerals, and shells, are each highly interesting objects of investigation, and of thought, and no pursuit is better calculated to expand and exalt the powers of the mind than the study of nature. In the city, where only the works of art are to be found, a great variety of other objects may enlist the attention. In walking for exercise, the form should be erect, the muscles of the arms and chest be unrestrained, and allowed that free use which nature designed them to enjoy, and every part of their dress should be loose and easy.

573. Dancing is also a good exercise for young ladies. It brings into action a large part of the muscles of the body and lower limbs, and gives gracefulness and power of motion to the whole body. It is unfortunate, however, that this exercise has so often been made an occasion for midnight carousals and dissipation, that the very idea of dancing awakens a train of unwelcome associations, which every moral mind revolts against. Dancing, in itself, is an innocent and useful amusement, which should be rescued from the degradation into which it has fallen by the abuse of vicious indulgence. In crowded assemblies, in heated rooms, and at late hours of night, dancing is undoubtedly most pernicious, and we would earnestly condemn the practice under all such circumstances. We are confident that if the more opulent class of society were less censorious in regard to the amusement itself, and would direct their remonstrances against the evils associated with it, their efforts for reform would be more successful. In the ball-room, the air is usually exceedingly impure, and often over-heated, and the excitement of the dance is often prolonged after the perspiration has started forth in gushing streams from every pore, and the body is fatigued and exhausted. Ladies who will frequent such assemblies, can never be expected to dress in any other than the most imprudent manner imaginable, with portions of the person wholly unprotected, and the vital organs so bound up that the least motion disturbs the action of the heart and lungs, which

§ 568. What is said of the importance of the muscles in all the actions of life?—Upon what does the strength of the muscles depend?—How does muscular exercise affect the nutrition of the body?—Why should exercise and rest be alternate?—Upon what does the force with which the muscles contract depend?—What is said of the *training* of pugilists? 569. What is said of the natural propensity of children to exercise, and of the duty of parents to afford them the means of exercise? 570. What further remarks are made on this subject? 571. What is said of the customs of society, as debarring young ladies from the benefits of exercise?—What are the consequences of this system?—Why are female operatives so often unhealthy?

§ 572. What circumstances are requisite to render the exercise of walking most beneficial? 573. What is said of dancing, as an exercise?

can perform their functions with difficulty, even when perfect rest is enjoyed. While the body is in this condition, there is every now and then an exposure to currents of air, and always to a ride or walk in the night, at that late hour, when it is said to be coldest and darkest, and when all power of resistance is exhausted by fatigue. Those who dance for exercise should do so in a loose dress, in a cool, well-ventilated room, or in the open air, with the attendance of only a few friends. The exercise should not be continued till fatigue is induced, or till profuse perspiration ensues. Two hours each day is abundance to be spent in this manner.

574. The triangle, hoop, ball, and dumb-bells, are also appropriate means of exercise. Jumping the rope is also highly useful, but we have known young persons very much injured by continuing this exercise too long. Every seminary or school for young ladies should be provided with broad, open grounds for fair weather, and open verandas for cloudy weather, together with a liberal supply of instruments for exercise. There should be as great a variety of amusements as possible—the more the better. During the spring, summer, and autumn, they should be encouraged to ramble in the open fields or forests, where these are accessible, in search of objects of natural history. Horseback-riding, with a spirited and safe horse, is well adapted to promote health in all persons. With a good horse, the mind and feelings are often most intensely interested, and every particle of blood receives a new impulse, and circulates with renewed activity through all the vessels. To one who knows how to admire and appreciate this noble animal, horseback-riding is a most delightful mode of exercise and amusement.

575. Men have a much wider range of exercise than females. Field-sports are always open and proper for men, of all ages, unless clergymen are to be prohibited on account of the sacredness of their profession. Many persons, who ought to know better, are ready to censure clergymen for indulgence in any sort of amusement, as though derogatory to their official dignity. No class of persons are more self-denying, or more disinterested in their efforts for the welfare of their fellow-men, than ministers of the Christian religion, and no class suffer so much for the want of bodily exercise. There can be no doubt that, as a class, the clergymen of this country would be far more useful, if they were allowed to indulge freely in what are called sports and amusements; for it cannot be denied, that sporting with the gun, or fishing-rod, or riding a spirited horse, constitute the very best kind of exercise for sedentary men. If they were allowed to take such exercise freely, they would have less occasion to leave their churches vacant, two or three months of the year, for a resort to the watering-places, a journey, or a foreign tour, in order to recruit their health.

There is such a variety of ways in which exercise may be taken, that no rule can be given as to the kind of exercise each individual may indulge in. For the most part, that which is most agreeable, or that which interests the mind, at the same time that it calls into action the muscles, will be found most useful. Some are most interested in field-sports, or the various games of quoits, ball, wicket, &c.; others can more happily combine usefulness and pleasure in manual labor. Young ladies, if they choose, will find the broom and brush very efficient instruments of exercise. The sedentary of the other sex may be equally benefited by using daily the saw and the axe. Gardening, too, in the season of it, to those who are fond of nature as exhibited in the up-rising shoot, and the opening bud and flower, affords the means of most wholesome exercise to the body, and most interesting diversion to the mind.

BATHING.

576. As a means of promoting health, bathing is next in importance to bodily exercise. Indeed, bathing, when followed by friction, is itself good exercise. The application of water to the human body is highly useful, both as a purifier and a tonic. The skin acts as an organ of excretion in throwing off from the body portions of matter that have become useless, and would produce disease if retained. It is supposed (§213, 217) that, in the skin of an ordinary-sized man, there are about seven millions of pores, through which some two and a half pounds of waste matter passes off every twenty-four hours. A considerable portion of this is the watery fluid called perspiration. But there is a constant tendency for the more solid portions to become deposited on the skin, and to form incrustations on its surface, thereby interfering with, and in some instances preventing, to a great extent, the performance of this function, so indispensable to healthy vital action. It is well known, that the functions of the skin have an important influence on the health of the lungs and liver. When the pores of the skin are clogged up, and its secretions retained, the blood becomes burdened with the accumulating impurities, which are carried to the lungs and liver, to render the performance of the natural functions of both of these organs more difficult and laborious, while their strength is all the while impaired by the impure condition of the nutritive fluid. On this account, frequent bathing is indispensable to the health of the liver and lungs. Bathing is also necessary for the health of the skin, since there is a constant exfoliation of the cuticle, which ought to be removed. This can often be seen, in a shower of flakes, by rubbing for a few minutes the skin of a person who neglects bathing.

577. Cold water, when applied to the hands and face, is grateful and refreshing to all persons; and in those accustomed to its use, it is equally refreshing to the whole body. The oriental custom of offering water for washing, as the first act of hospitality to the weary traveller, is worthy of our admiration. Even food to the hungry is scarcely more refreshing than the bathing of the tired limbs with cold water. When applied to the skin, it produces an instantaneous contraction of the capillary vessels, forcing out their contents, and admitting a fresh supply of blood. An impulse is thus given to the whole circulation, while new tone and vigor is imparted to the capillary and nervous systems. Cold water to the skin is thus one of the best of tonics. It relieves internal congestion, calms mental excitement, quiets nervous irritability, carries off feverish heat when it exists, and equalizes the circulation.

578. Water may be applied to the skin, according to the fancy and convenience of each individual, either as a warm bath, a cold plunge, a douche, a shower, or with a sponge. The warm bath is useful chiefly as a special means of cleanliness, and as a relief to colds, and to internal congestion or inflammation. In cases of incipient inflammation, it is unquestionably one of our best remedies, inviting the blood to the surface, and thereby relieving the internal organs. The plunge is very agreeable in warm weather. The douche is useful mainly for the relief of particular parts. The shower-bath is probably preferable to all others as a promoter of health, and the sponge is recommended for its convenience, in the absence of other means. The shower-bath gives a general shock to the system, and is followed by a delightful glow of warmth, and general activity of the whole circulation. It cannot, however, be used beneficially by all persons. In the aged, and those in a low state of health, there is not sufficient vigor to bring on a healthy rëaction. The cold shower-bath should, therefore, never be used, unless it is soon followed by a general warmth. The shower-bath, of late, has lost much of its popularity from its improper application. In many instances, it is so constructed that its effect is more like a hail-storm than a gentle shower. Very few persons have courage or strength to endure the torrents that pour from many which are offered for sale at the shops. The streams of water should be small, should not fall from too great a height, and should be so arranged as not to compel the wetting of the head at first. Applied in this way, the shower-bath is a most delightful means of promoting health.

579. Bathing of the whole person, in some form, should be performed daily, or, at least, every other day. Children should be accustomed to it daily, after the first year. If it is practised under the age of one year, the exposure should be very brief, and great pains taken to produce an immediate rëaction. The morning is the best time for the use of the bath, though it gives such activity to the circulation, and to the absorbents in particular, that breakfast is needed almost immediately after. The liability to sudden cold is greatest when the body is fatigued, and the cold bath should be used

§ 574. What are mentioned as the abuses of dancing, and what are their consequences?—In order to make dancing beneficial, how should it be conducted?—What other means of exercise are mentioned as beneficial to females? 575. What is said in regard to the indulgence of clergymen in field-sports, and other kinds of exercise?—What general remarks are made in regard to the kind of exercise proper for individuals? 576. What is said of the importance of bathing?—State the mode in which the skin acts as an excretory organ, and the reasons why healthy action of the liver and lungs is promoted by bathing.

§ 577. What are the effects of cold water when applied to the skin? 578. What are the various means of applying water to the skin?—What is said of the advantages of the warm bath?—What of the shower-bath? 579. How often, and at what hours should bathing be performed?—By what should the bath be followed?

with great caution. Under such circumstances, the warm bath is usually preferred, as safer and more agreeable. Bathing, of whatever sort, should be followed by generous friction of the whole surface of the body. It promotes the health of the skin, imparts additional vigor to the circulation, and brings on a healthy rëaction.

ON THE USE OF MEDICINES.

580. By many persons, medicinal agents are regarded as essential means of promoting health, and it therefore seems necessary briefly to investigate their influence on the animal economy, and make some observations in regard to their proper use. Health, we are bound to look upon as the natural condition of every living being; a condition in which all the vital forces act with uniform harmony throughout the various tissues and organs. This state, however, can be enjoyed only while the functions of the body, and the agents that act on it from without, are in perfect accordance with the laws of vital action in each individual. When there is any departure from that high state of vitality denominated health, either in the due performance of any of the functions, or in the condition of any of the organs, disease is said to exist. Disease is, therefore, an unnatural state, in which some one or more of the organs or tissues are impaired, either in their structure or function. Disease, it is true, may be hereditary, or transmitted from one to another; but it is, nevertheless, a departure from the natural condition, and is an artificial state, brought about, in a majority of instances, by man's own agency. Nothing can be more absurd than the common notion, that disease is necessarily contingent to our nature; for nature, however depraved in other respects, is faultless in this. The body, with its several organs, will always be in health, so long as all the conditions of vitality are fully supplied.

581. Equally unnatural to the animal economy is the use of medicine. It constitutes no part of our natural aliment, and is wholly an artificial agent, brought to our aid for the relief of those ills that our own imprudence and wrong actions bring on us, and therefore can never be said to be natural to man. The necessity of medicine for the human system, is mostly created by man's own wrong-doing. The kind and character of medicine, proper for man, must therefore be ascertained by his own wisdom and experience. The mineral and vegetable world both abound with an infinite variety of agents, that produce almost as great a variety of effects on particular organs of the body. We are not, however, to suppose that an all-wise Creator, in his infinite goodness, has fitted up this world of beauty and variety, as one vast drug-shop, for the relief of human sufferings, and for the mitigation of those diseases that men bring on themselves, by the violation of the very laws by which He has ordained they shall maintain their existence. Disease is an unnatural condition, and no natural remedy exists in the wide world for its relief. Medicines, so far as is known, relieve disease by exciting in the affected organ a new or a different action; or, as some would explain it, medicine cures disease by substituting a disease of its own, which nature can then cure for herself. Whatever the *modus operandi* of medicines may be, they unquestionably produce their effects by increasing or diminishing the natural action of the organ subject to their influence. Medicines may, therefore, be regarded as always interfering, in some degree, with the natural process of vital action; and they can never be said to be harmless, unless they are wholly inert. Medicines and disease are alike evils in the animal economy. When disease actually exists, we regard the effects of medicine as the least of the two evils, and use it accordingly. For instance, in jaundice, from inactivity of the liver, there is an excessive accumulation of carbonaceous matter in the system; the blood is rendered turbid by its presence, and allows the carbon to remain in the coats of the skin in such quantities as to color the whole surface. To procure relief from this disease, medicines are used which excite an increased secretion of bile by the liver, and which stimulate the bowels to increased action, in order to carry off the bile poured into the duodenum. By this process, the liver and bowels may become, in a certain sense, worn out, just as a piece of machinery is worn out by being propelled beyond its usual velocity.

582. The true way of preserving health, is not by even a judicious use of such medicines as may cure all the diseases our imprudence may create, but in so living as *to avoid the disease*, and so escape the necessity for the medicine. Some medicines, however, contain such ingredients as furnish certain elements of the blood, and may therefore be regarded as nutritive agents, since they actually contribute materials for the renovation and growth of the tissues. But most of the medicines in popular use are such as stimulate and excite some of the organs. Cathartics, laxatives, and all the so-called purifiers of the blood, have a tendency to weaken the natural tone of the organs, and their use creates more or less necessity for their repetition. Nearly all the patent medicines, that promise a cure for every ailment which affects mankind, are composed of substances possessing properties more or less cathartic; and it is worthy of note, that almost all their proprietors advise a continued use—another box, or another bottle—with a discount to such as purchase by the dozen. Nor is this all; a kind of competition has sprung up, for selling the largest quantity of these mixtures for the smallest sum of money, just as though the degree of health was to be measured by the amount swallowed in a given time. Instead of a few ounces, for occasional use, medicine is now sold by the quart, as a kind of daily beverage. The Americans and English are said to excel all other nations in the consumption of medicine; and it is equally notorious, that dyspepsia is more prevalent in England and America than in any other countries. It is also true, so far as our own observation extends, that those families and communities which consume most of these popular panaceas, are most sickly, and furnish employment for the largest number of physicians. One reason for this may be, that those persons who are constantly supplied with pills and elixirs, allow themselves greater liberty of indulgence, since a remedy for all evil consequences is at hand. The habitual use of medicine, except for special reasons, is highly injurious to the human system. In slow chronic diseases, a long-protracted use of remedies is indispensable to recovery, but the habit of medicine-taking, even then, is a bad one, and is to be endured only because of its necessity.

583. It is a proverb, that "a physician will not take his own prescriptions." The truth of this is liable to some exceptions, though there are probably none who use so little medicine for themselves, or their families, as physicians. Yet no class of persons are subjected to more vicissitudes of exposure and fatigue, or whose business-habits are more unfavorable to health. Instead of resorting to medicine for every slight ailment, judicious physicians practice self-denial in regard to the indulgence of appetite, and use with more diligence the ordinary means of promoting health. The use of medicine, however, cannot always be avoided. When disease has made an attack on a vital organ, its progress must be checked, and the organ relieved by remedial agents; but the time when medicine is to be used, as well as the selection of the appropriate agent, is of more importance than most men seem to suppose. When there is a little anxiety or alarm, ignorance is ready to make use of any thing, or every thing that can be thought of, and dissatisfaction is often expressed if there should chance to be any possible means untried, while wisdom dictates a reliance upon a few remedies, or a single well-established one.

584. As a general rule, no person is competent to prescribe medicine for himself. Even the experience, and proverbial coolness of the physician, do not fit him to comprehend his own case, when under the influence of serious disease. Our feelings have such an influence over our bodies, that very few persons can judge correctly of their own symptoms. If you attempt to count your own pulse, with any degree of anxiety, it will immediately become more frequent. One who is naturally desponding, will think himself much more dangerously ill than he really is, while another, who is full of hope and ambition, will overlook a very serious illness, as of little consequence.

585. If physicians cannot prescribe safely for themselves, how much less competent are those who are ignorant of the properties and powers of medicine, and who know but very little, if any thing, of their own organization, or of the symptoms of disease? The habit of thinking about, and studying our own symptoms and feelings, is

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§ 580. What is said of health and disease, as the natural and unnatural conditions of the body? 581. What is said of the necessity of medicine?—By what is that necessity created?—How does medicine relieve disease?—When only may a medicine be considered harmless?—What is said of the evil effects of medicine, when used in curing disease? What instance is given?

§ 582. What is the true way of preserving health?—Of what nature are most of the popular medicines?—What is said of the use of these medicines, and of their effects, and of the habit of medicine-taking in general? 583. Why do physicians take less medicine than other persons?—What is said of the importance of selecting a proper remedy, and of using it at a proper time? 584. What general rule is given for prescribing medicines, and what are the reasons for this rule? 585. What is the effect of studying our own symptoms?—What, then, is the proper course to be taken by the sick?

PLATE XIV.

CHANGE OF FORM.

The erect attitude, or a capacity and organization to stand and walk erect, has always been given as one of those characteristics that indicate man's superiority over all other animals. An erect form is therefore equally essential to the gracefulness and dignity of his external appearance, and to the health of the various internal organs which constitute his delicate and complicated machinery.

During the first twenty years, his bones, like those of all young animals, are in a soft, pliable state, that admits of their natural form being moulded into almost any shape; as is very evident from the customs of the Flat-head Indians and the Chinese females, and from the deformities that exist among Americans. The miniature feet of the Chinese and the flat heads of the Indian, as well as the rounded shoulders, the distorted spines, and the contracted chests that characterize (according to the best medical authorities) from one-half to three-fourths of the individuals in the best classes of society, are most melancholy demonstrations of the susceptibility of the human form to yield to the slightest causes of deformity.

The greatest susceptibility to change of form should not be referred to the bones alone:—the cartilages which separate the vertebræ of the back are so soft and yielding, as to be easily accommodated to any position which may be habitual. If an individual sits bent forward a few hours each day, as in Figs. 1 and 2, the anterior edge of the cartilage will be absorbed, and become thinner, giving a permanent curvature in the adult, as is represented in Fig. 4. Or, if there be an habitual inclination to one side, as in Fig. 3, the cartilages will become thinner where the pressure is the greatest, forming a permanent lateral curvature, as in Fig. 5. In like manner, persons who habitually maintain, while sitting or standing, the positions represented in Figs. 6, 7, 8, 9, and 10, will almost invariably retain the elegance and dignity of an erect form.

Scholars who are compelled to sit six hours each day on a stool or bench without any support for the back, and so high that the feet cannot rest on the floor; and those who write at a table or a desk too low for the seat they occupy, cannot fail to contract more or less lasting departure from the elegance and dignity of an erect form. If we have any proper regard to personal appearance, or any due estimate of the value of health, we cannot attach too much importance to the adaptation of seats and desks to the wants and comforts of those who are to occupy them. Neglect, in the trifling matter of an appropriate chair and table for the growing young, has marred the beauty of many a fair form, and created an ugly, uncouth deformity, which cannot be remedied by all the braces and supporters of modern invention.

The form of the chest can be changed with even greater ease than the spine. The ribs are attached to the breast-bone by means of long flexible cartilages, which yield to very slight pressure when applied round the waist. Fig. 11 represents the outlines of a natural female figure, and Fig. 12 is part of the skeleton of the same. Fig. 13 is an outline of a female figure after it has been permanently remodelled by fashionable dress. Fig. 14 is part of the skeleton with the diameter of the thorax round the waist reduced to about one-half its natural size. Such melancholy specimens of infringement on the natural capacity of the respiratory organs are by no means rare. The probability is, that nearly all females in the fashionable circles have contracted more or less the walls of the chest, though very few seem conscious of wearing tight garments.

The flexibility of the cartilages is so great, that the slight pressure of a "*snug fit*," constantly applied to the young miss who is growing rapidly, or even to the young lady, is sufficient in a few years to produce a very marked deviation from nature. A little gentle and apparently harmless pressure, extended to each day through successive years, accomplishes with very great ease a work which it would require great violence to perform in a few days or weeks.

PL. XIV.

CHANGE OF FORM.

Fig. 7. Fig. 2.

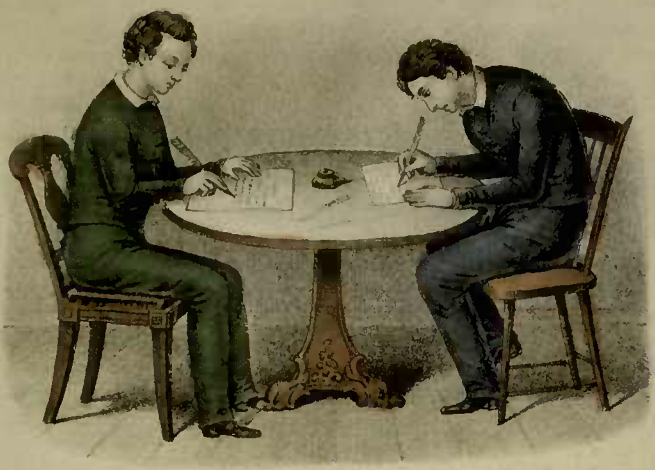


Fig. 3. Fig. 8.

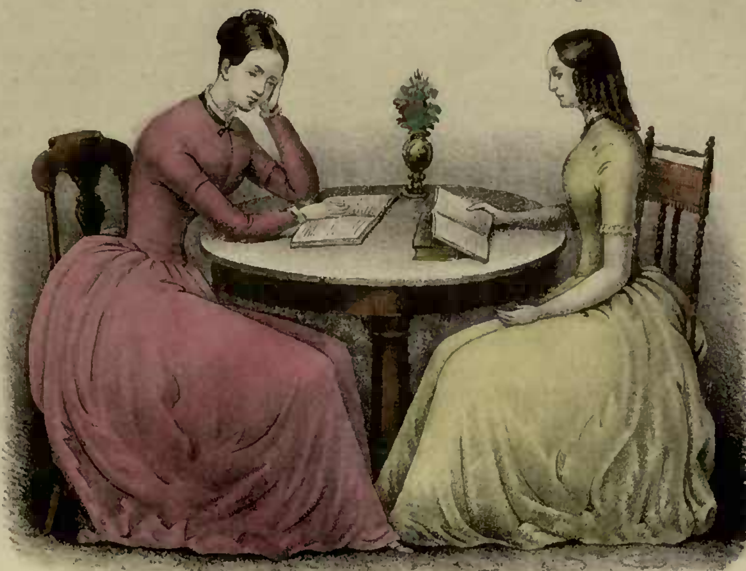


Fig. 10. Fig. 4.

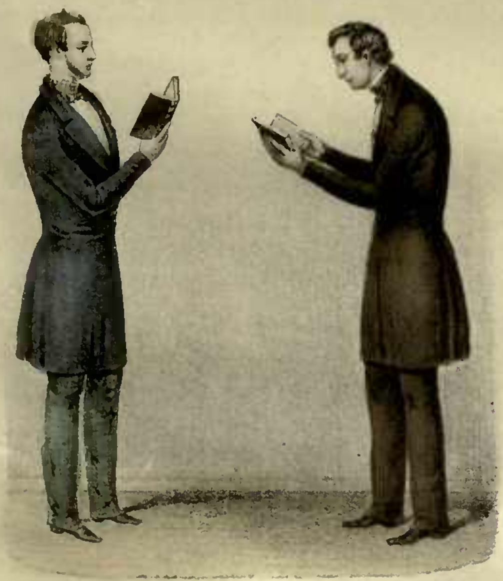


Fig. 1.

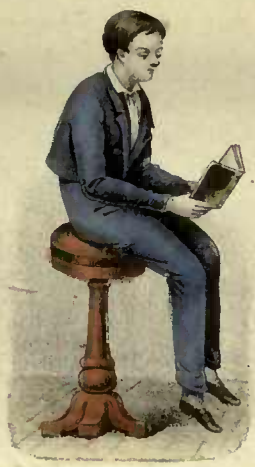


Fig. 5. Fig. 9.

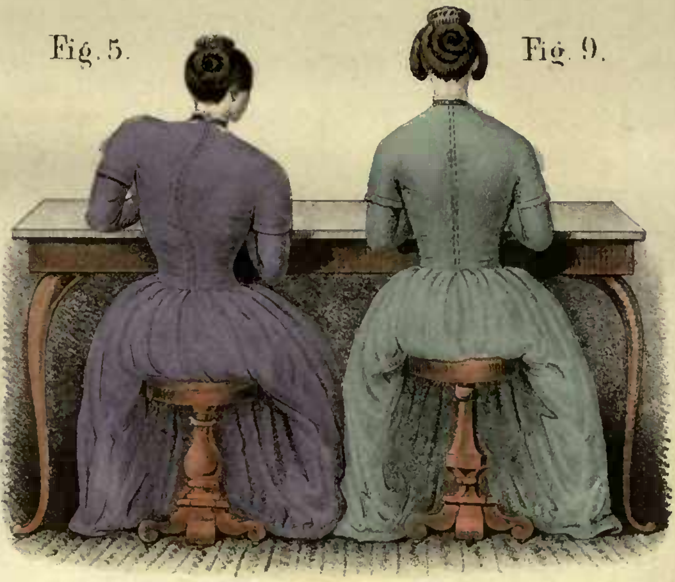


Fig. 11.

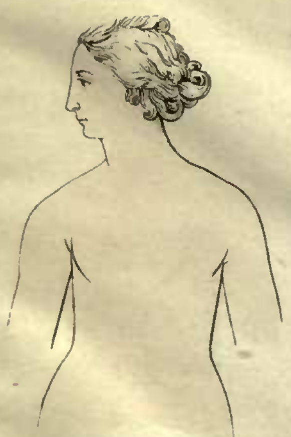


Fig. 12.

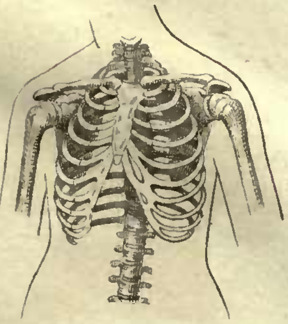


Fig. 6.

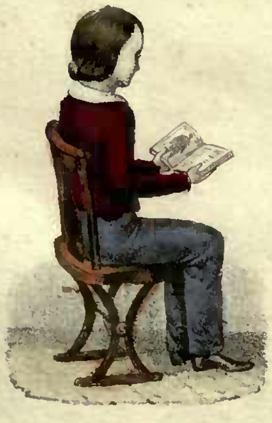


Fig. 14.

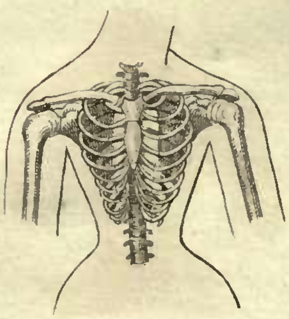
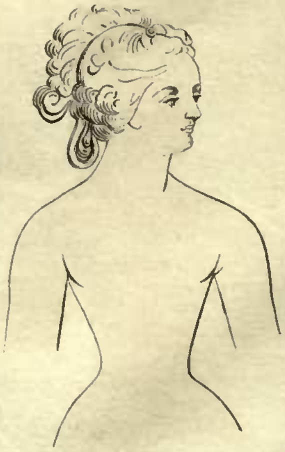


Fig. 13.



Lith. of Kellogg. Entered, according to Act of Congress, in the year 1851, by Kellogg & Comstock, in the Clerk's office of the District Court of Connecticut. Hartford Conn.

also injurious. Most men are so constituted, that when the mind is turned to the investigation of their own pains and ills, the latter assume new strength and frequency; and an illness, otherwise comparatively mild, becomes grave and formidable. When we have so far failed of obeying the laws of health as to become sick, the proper course is, to call in the aid of superior skill and experience: not that it is our design to recommend the employment of a physician for any interest we entertain for the profession, but because we are honest in the conviction that a vast amount of suffering would be saved thereby, and an infinite amount of medicine-taking would be avoided, while disease would be more judiciously treated in its incipient stages, and often prevented. In the practice of self-prescribing, men as often hit wrong as right, and as often aggravate disease as relieve it. If all the patent and domestic medicines were swept from the land, we are confident that the demand for physicians would be diminished, rather than increased, and a vast amount of trifling with human life avoided. The legitimate use of medicine is, to relieve disease: it should be used for no other purpose, and should only be administered by a person thoroughly acquainted with the characteristics of disease, the wants of the human system, and the properties of medicinal substances.

586. For slight ailments, that arise from the excessive indulgence of the appetite or passions, or from too much fatigue, anxiety, or care, the best remedies are a plain diet, relaxation from accustomed labors, and a rigid observance of all those natural means that promote health. The various organs thereby regain their tone and vigor, and all works well again, without the interference of a foreign agent in nature's own operations. Such a course is always beneficial in its influence, and highly conducive to health and long life. The powers of nature, when her operations are not interfered with, are sufficient to ensure the long continuance of uninterrupted health; and the part of wisdom, is to watch and guard, with untiring assiduity, this greatest of all blessings, while it is in our possession. The fact that a majority of our race meet a premature death, in consequence of neglect and imprudence, should admonish us to be ever vigilant and watchful. For the conclusion is irresistible, that health is a blessing entrusted to us only on compliance with those laws that are inseparable from our existence. Next to the obligations we owe our Creator, the preservation of health should be an object more sacred than all others. To attain it, the business of life, and the habits of each day, should have a direct reference. Uniformity should characterize all our habits, and extend to our hours of labor and rest, of exercise and sleep, as well as to our dress and diet. Then may we hope, under the blessing of a kind Providence, to see many days of uninterrupted health, till death shall be introduced, as a kind friend, to release us from a body worn out with many years.

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§ 586. What are the proper remedies for slight ailments?—What concluding remarks are made upon this subject?

GLOSSARY.

Abdo'men (L. *abdo*, to hide). So called from its containing the intestines, &c.

Abduc'tor (L. *abduco*, to draw from). *Abducent.* A muscle whose office is to draw one part of the body away from another.

Abra'sion (L. *abrado*, to shave off). The act of wearing or rubbing off; as the mechanical removal of the epidermis.

Acetab'ulum (L. *acetum*, vinegar). Literally, a vinegar-cruet. Hence it denotes the *cup-like* cavity of the hip-bone, which receives the head of the thigh-bone.

Achil'lis Ten'do (tendon of Achilles). The strong tendon of the gastrocnemius and soleus muscles, which is inserted in the heel.

Achromat'ic (*a* priv., Gr. *chrōma*, color). Without color; lenses are so designated, in which the dispersion of light is corrected.

Acro'mion (Gr. *ăkros*, highest, and *ōmos*, the shoulder). The humeral extremity of the spinous process of the scapula.

Adduc'tor (L. *adduco*, to draw to). A muscle whose office is to bring one part towards another. Thus, the rectus internus is also called *adductor* oculi, from the action of this muscle in turning the eye towards the nose.

A'dipose Mem'brane, or Tis'sue. That which incloses the *adeps*, or fat.

Affin'ity (L. *affinitas*, relationship). That kind of attraction by which different classes of bodies combine to form *new* bodies, as an acid with an alkali, forming a salt.

Albu'men (L. *albus*, white). Albumen is of two kinds, animal and vegetable: 1. *Animal albumen* exists in two forms, the liquid and the solid. In the *liquid* state, it is a thick glairy fluid, constituting the principal part of the white of egg. In the *solid* state, it is contained in several of the textures of the body, as the cellular membrane, the skin, glands, and vessels.—2. *Vegetable albumen* closely resembles animal albumen, and has been found in wheat, rye, barley, peas, and beans.

Alveo'li (L. dim. of *alvei*, channels). The alveolar process, or the sockets of the teeth. Hence the term alveolar, as applied to the arteries and veins of the sockets of the teeth.

Ammo'nia. A transparent, colorless, pungent gas, formed by the union of nitrogen and hydrogen.

Amphib'ia. The second class of the Vertebrata, comprising amphibious animals, which commence their larva state as fishes, and undergo various degrees of metamorphosis in advancing towards the condition of reptiles, as the frog, &c.

Anastomo'sis (Gr. *aná*, through, and *stóma*, a mouth). The communication of vessels with each other, as of the arteries with the veins, which, by touching at numerous points, form a net-work or reticulation. See *Inosculation.*

Anat'omy (Gr. *ánatémnō*, to cut up). The science of organization; the science whose object is the examination of the organs or *instruments* of life. Animal anatomy is divided into *human anatomy* and *comparative anatomy*, according as it treats of the organization of the human body, or of that of other animals.

An'eurism (Gr. *áneurúnō*, to dilate). The dilation of a vessel or vessels.

Angiol'ogy (Gr. *ággeion*, a vessel, *lógos*, a discourse). The science of the vascular system.

Animal'cules (L. dim. of *animal*). Microscopic animals. They doubtless exist in the atmosphere, and in all rivers or ponds.

Ante'rior (Latin). Before; as applied to vessels and nerves.

Aort'a (Gr. *aèr*, air, *teréō*, to keep; as having been formerly supposed to contain only air). The great artery of the heart. It is distinguished into the *ascending* and *descending.*

Aponeuro'sis (Gr. *apó*, from, and *neūron*, a nerve). A fibrous or tendinous expansion, erroneously supposed by the ancients to be that of a nerve; in the thigh, it is termed the *fascia lata.*

Apoplex'y (Gr. *apó* and *pléssō*, to strike). Apoplectic fit or stroke. The term denotes congestion or rupture of the brain, with sudden loss of sensation and motion.

Append'ix (L. *appendo*, to hang to). A process or appendage; something appended to another part, without being essential to the existence of this part.

Aq'ueduct (L. *aquæ ductus*, a water-course). A term applied to certain *canals* occurring in different parts of the body.

Arach'noid Mem'brane (Gr. *aráchnē*, a spider, and *eidos*, likeness). The fine *cobweb-like* membrane situated between the dura and pia mater. It is the serous membrane of the cerebro-spinal centres.

Ar'bor Vi'tæ. Literally, *tree of life.* A term applied to the *arborescent* appearance Presented by the cerebellum, when cut into vertically.

Aro'ma (Gr. *ari*, intensely, and *ozō*, to smell). The odorous principle of plants.

Ar'tery (Gr. *aèr*, air, and *teréō*, to hold). A vessel which carries the blood from the heart; formerly supposed, from its being found empty after death, to contain only air.

Arte'rialization. The conversion of the *venous* into the *arterial* blood; a term applied to the change induced in the blood as it passes through the lungs, by the evolution of carbonic acid, and the abstraction of oxygen from the air.

Articula'ta (L. *articulus*, a joint). Articulated or jointed animals; one of the four great divisions of the animal kingdom.

Articula'tion (L. *articulus*, a joint). The mechanism by which the bones of the skeleton are connected with each other.

Aryt'ænoid (Gr. *arútaina*, a ewer, and *eīdos*, likeness). A term applied to two triangular cartilages of the larynx.

Asphyx'ia (*a*, priv. Gr. *sphúxis*, the pulse). Originally, interrupted pulse; but more recently and generally, interrupted respiration, as in hanging, drowning, &c.; suspended animation; apparent death.

Astrag'alus (Gr. *astrágalos*, a die). The ankle-bone: the analogous bones of some animal were used by the ancients as dice.

At'las (Gr. *tláō*, to sustain). The uppermost of the cervical vertebræ; so named from its supporting the head, as Atlas was said to support the world.

At'om (Gr. *témnō*, to cut). An ultimate particle of matter, incapable of further division.

Attol'lens (L. *attollo*, to lift up). A muscle which draws any part upward, as the *attollens auriculam*, or superior auris, which raises the ear.

Au'ditory (L. *audio*, to hear). Belonging to parts connected with the sense of hearing.

Auric'ula (L. dim. of *auris*, the ear). An auricle; the prominent part of the ear. Also, the name of two cavities of the heart.

Automat'ic Motions (Gr. *automatos*, of his own accord). Those muscular actions which are not dependent on the mind.

Autop'sia (Gr. *autôs*, oneself, and *optomai*, to see). Post-mortem examination. Inspection of the body after death.

Axil'la (L. *ala*, a wing). The arm-pit; the space between the side of the chest and the shoulder. Hence the term *Ax'illary*, applied to parts belonging to the *axilla.*

B

Ball-and-Sock'et. A species of movable articulation, as that of the hip.

Bi'ceps (L. *bis*, twice, and *caput*, the head). Two-headed, or having two distinct origins, as applied to a muscle of the thigh and of the arm.

Bicuspida'ti (L. *cuspis*, a spear). Having two tubercles; as applied to the two first pairs of grinders in each jaw.

Bifurca'tion (L. *furca*, a fork). The division of a vessel, or nerve, into two branches, as that of a two-pronged fork.

Bima'na (L. *manus*, a hand). Two-handed; as man: the first order of the Mammalia.

Bi'lis. Bile, gall, or choler; the secretion of the liver.

Bil'ious. A term employed to characterize a class of diseases caused by a too copious secretion of bile.

Brach'ium (Gr. *brachiōn*, an arm). The arm; the part from the shoulder to the elbow. Whence *Brachial*, pertaining to the arm.

Branch'ia (Gr. *bráпgchia*, gills). Gills; filamentous organs for breathing in water.

Bronch'us (Gr. *bróngchos*, the windpipe, from *bréchō*, to moisten). The windpipe; a ramification of the trachea; so called from the ancient belief that the solids were conveyed into the stomach by the œsophagus, and the fluids by the bronchia.

Bronch'ial-tubes. The minute ramifications of the bronchi, terminating in the *bronchial cells*, or air cells, of the lungs.

Bronchi'tis. Inflammation of the bronchi, or ramifications of the trachea.

Buccina'tor (L. *buccina*, a trumpet). The trumpeter's muscle; a muscle of the cheek, so called from its being much used in blowing the trumpet.

Bur'sæ Muco'sæ (*mucous bags*). Small sacs situated about the joints, being parts of the sheaths of tendons.

C

Cæ'cum, or Cœ'cum (L. *cæcus*, blind). The first part of the colon, or *blind* intestine.

Calca'neum (L. *calx*, the heel). The *os calcis*, or heel-bone.

Cal'lus (Latin, *hardness*). New bone, or the substance which serves to join together the ends of a fracture, and to restore destroyed portions of bone.

Can'cer. Literally, a *crab.* The term is applied to the disease from the claw-like spreading of the veins.

Canine'-Teeth (L. *canis*, a dog). Eye-teeth; the four immediately adjoining the incisors.

Cap'illary (L. *capillus*, a hair). Resembling a hair in size; a term applied to the *vessels* which intervene between the minute arteries and veins.

Capsu'la (L. dim. of *capsa*, a chest). Literally, a little chest. A capsule or bag, which incloses any part.

Car'bon (L. *carbo*, a coal). A substance well known under the form of coal, charcoal, lamp-black, &c. In chemical language, it denotes the pure inflammable principle of charcoal; in its state of absolute purity, it constitutes the *diamond.*

Car'dia, (Gr. *kardia*, the heart). The entrance into the stomach, so called from being near the heart.

Car'diac (Gr. *kardia*, the heart). Relating to the heart.

Carot'id (Gr. *karóō*, to induce sleep). The name of two large arteries of the neck; so called from an idea that tying them would induce stupor.

Car'pus (Gr. *karpós*, fruit). The wrist. The *ossa carpi*, or carpal bones, are eight in number, and form two rows.

Car'tilage. Gristle. It is attached to bones, and must be distinguished from the ligaments of joints and tendons of muscles.

Cau'da Equi'na, or horse's tail; the final division of the spinal cord; so called from the disposition of the nerves which issue from it.

Cerebel′lum (dim. of *cerebrum*). The little brain, situated behind the larger, or cerebrum.

Cer′ebrum (Gr. *káre*, the head). The brain; the chief portion of the brain, occupying the whole upper cavity of the skull.

Ceru′men (L. *cera*, wax). The waxy secretion of the ear, furnished by the *cerumenous glands*.

Cer′vĭx. The neck; the hinder part of the neck: the fore part is called *collum*.

Chest. *Thorax*. An old English term, commonly traced to the Latin *cista*.—"When it is considered that the same word was anciently used for a *basket*, the appropriation of it to the human thorax will appear quite natural to any one who has ever seen a skeleton."—*Forbes*.

Cho′rium (Gr. *chórion*, skin, leather). The dermis, or innermost layer of the skin.

Chyle (Gr. *chulòs*, juice). The milk-like fluid absorbed by the lacteal vessels.

Chylifica′tion (L. *fio*, to become). The process by which the chyle is separated from the chyme.

Chyme (Gr. *chumòs*, juice). The semi-fluid matter which passes from the stomach into the duodenum.

Chymifica′tion (L. *fio*, to become). The process by which the aliment is converted into chyme.

Cil′iary (L. *cilia*, eyelashes). Belonging to the eyelids.

Cil′iary Cir′cle or Lig′ament. A kind of grayish ring, situated between the choroid membrane, the iris, and the sclerotica.

Cil′iary Pro′cesses. Small membranous bodies, surrounding the crystalline lens in a radiating form.

Cineri′tious (L. *cineres*, ashes). Ash-colored; a term applied to the exterior or cortical part of the brain.

Clavic′ula (L. dim. of *clavis*, a key). The clavicle, or collar-bone; so called from its resemblance to an ancient key.

Coc′cyx (Gr. *kókkux*, a cuckoo). The lower end of the spine; so called from its resemblance to the cuckoo's beak.

Coch′lea (Gr. *káchlos*, a conch). A cavity of the ear, resembling the spiral shell of the snail.

Co′lon (Gr. *kōlon*, quasi *koilon*, hollow). The first of the large intestines, commencing at the cœcum, and terminating at the rectum.

Co′ma (Gr. *kōma*, drowsiness, from *kéō*, to lie). Drowsiness; lethargic sleep; dead sleep; torpor.

Complex′us (L. *complector*, to comprise). A muscle situated at the back part of the neck. It is so named from the intricate mixture of its muscular and tendinous parts.

Concus′sion (L. *cancutio*, to shake together). A term applied to injuries sustained by the brain, and other viscera, from falls, blows, &c.

Con′dyle (Gr. *kóndulos*, a knuckle). A rounded eminence in the joints of several bones, as of the humerus and the femur.

Conges′tion (L. *congero*, to amass). Undue fullness of the blood-vessels.

Conjunc′tiva (L. *conjungo*, to unite). The mucous membrane which lines the posterior surface of the eyelids, and is continued over the fore-part of the globe of the eye.

Constrict′or (L. *constringo*, to bind together). A muscle which contracts any opening of the body, as that of the pharynx.

Contractil′ity (L. *contraho*, to draw together). The property by which bodies contract. 1. The property by which the fibrous tissues return to their former dimensions, after being temporarily extended. 2. The property of the muscular fibre, by which it shortens on the application of a stimulus; more properly, *Irritability*.

Cor′acoïd Pro′cess (Gr. *kórax*, a crow, and *eidos*, likeness). The upper and anterior point of the scapula; so called from its resemblance to a crow's beak.

Co′rium. Leather. The deep layer of cutis, or true skin, forming the base of the support to the skin.

Corn′ea (L. *cornu*, a horn). The anterior transparent portion of the globe of the eye.

Coro′na. A crown. Hence, the term *coronal* is applied to a suture of the head; and *coronary* to vessels, nerves, &c., from their surrounding the parts like a crown.

Corpus′culum (L. dim. of *corpus*, a body). A corpuscle, or little body.

Cos′ta (L. *custodio*, to guard). A rib.

Cox′a. The hip or haunch: the huckle-bone; the joint of the hip.

Cra′nium (Gr. *kára*, the head). The skull, or cavity which contains the brain, its membranes, and vessels.

Crib′riform (L. *cribrum*, a sieve, and *forma*, likeness). The name of the plate of the ethmoïd-bone, from its being perforated like a seive.

Cri′cos (Gr. *kríkos*, a ring). Whence *Cricoïd*, the name of the ring-like cartilage of the larynx.

Cru′ra. Plural of *Crus*, a leg; a term applied to some parts of the body, from their resemblance to a leg or root.

Cryst′alline (Gr. *krústallos*, ice). A term applied to the lens of the eye.

Cu′bitus (L. *cubo*, to lie down, from the ancients reclining on this part at meals). The fore-arm, consisting of the *ulna* and *radius*.

Cuboi′des (Gr. *kúbos*, a cube, and *eidos*, likeness). The name of a bone of the foot, somewhat *resembling a cube*, situated at the fore and outer part of the tarsus.

Cune′iform (L. *cuneus*, a wedge, and *forma*, likeness). Wedgelike; the name of three bones of the foot.

Cu′ticle (L. dim. of *cutis*). The epidermis, or scarf-skin.

Cu′tis (Gr. *kútos*, the skin). The true skin, as distinguished from the cuticle, epidermis, or scarf-skin.

D

Decussa′tion (L. *decusso*, to cross like an X). A term applied to parts which cross each other, as the optic nerve.

Degluti′tion (L. *deglutio*, to swallow). The act of swallowing.

Del′toid (Gr. *délta*, the Greek letter Δ, and *eidos*, likeness). The name of a muscle of the humerus, from its supposed resemblance to the Greek letter *délta*.

Denta′ta (L. *dens*, a tooth). The name of the second vertebra; so called from its projecting *tooth-like* process.

Der′moïd (Gr. *dérma*, skin, and *eidos*, likeness). A term applied to tissues which resemble skin.

Di′aphragm (Gr. *diàphragma*, a partition). The midriff: the transverse muscular partition which separates the thorax from the abdomen.

Digas′tricus (Gr. *dìs*, twice, and *gastèr*, a belly). Having two bellies: name of a muscle.

Diges′tion (L. *digero*, from *diversim gero*, to carry into different parts). In *Physiology*, the change of the food into *chyme* by the mouth, stomach, and small intestines; and the absorption and distribution of the more nutritious parts, or the *chyle*, through the system.

Dip′loe (Gr. *diploûs*, double). The cellular bony tissue between the two tables of the skull.

Disloca′tion (L. *disloco*, to put out of place). The displacement of the articular surfaces of a bone from their natural situation.

Dor′sum (Latin). The back; the round part of the back of a man or beast. Whence *Dor′sal*, appertaining to the back, as applied to a region, ligaments, &c.

Drop′sy (L. *hydrops*, from the Gr. *údròps*, water). An effusion of serous fluid into any of the natural cavities of the body.

Duode′num (L. *duodeni*, twelve). The twelve-inch intestine; so called from its being equal in length to the breadth of twelve fingers; the first portion of the small intestines, beginning from the pylorus.

Du′ra Ma′ter (*hard mother*). The outermost membrane of the brain.

Dys′entery (Gr. *dūs*, badly, and *entera*, the bowels). Inflammation of the mucous lining of the large intestines.

Dyspep′sia (Gr. *dūs*, and *peptō*, to digest). Indigestion; difficulty of digestion.

E

Efflu′via (L. *effluo*, to flow out). Exhalations, vapours, &c.

Elasti′city. The property or power by which a body compressed or extended returns to its former state.

Eleva′tor (L. *elevo*, to raise). A name applied to certain muscles, whose office it is to elevate any part.

Enam′el. The hard exterior surface of the teeth.

Enceph′alon (Gr. *èn*, in, *kephalē*, the head). The brain; the contents of the skull, consisting of the cerebrum, cerebellum, medulla oblongata, and membranes.

Epider′mis (Gr. *epi*, upon, and *dérma*, the skin). The cuticle, or scarf-skin; the thin horny layer which protects the surface of the integument.

Epiglot′tis. A cartilage of the larynx, situated above the glottis.

Epip′loon (Gr. *plēo*, to sail). The omentum; a membranous expansion which *floats* upon the intestines.

Epithe′lium (Gr. *títhēmi*, to place). The cuticle on the red part of the lips, and on the mucous membranes in general.

Eth′moid (Gr. *èthmòs*, a seive, *eidos*, likeness). Cribriform, or *sieve-like;* a bone of the nose, perforated for the transmission of the olfactory nerves.

Eustach′ian-tube. A canal which extends from the tympanum to the pharynx, called after Eustachius, its discoverer.

Excre′tion (L. *excerno*, to separate from). A general term for the perspiration, fæces, &c., which are separated and voided from the blood or the food.

Ex′cretory Duct (L. *excerno*, to separate from). The duct which proceeds from a gland, as the parotid, &c., and transmits outward, or into particular reservoirs, the fluid secreted by it.

Expira′tion (L. *expiro*, to breathe). That part of the respiration in which the air is expelled. Compare *Inspiration*.

Extens′or (L. *extendo*, to stretch out). A muscle which extends any part. It is opposed to *flexor*, or that which bends a part.

Exuda′tion. *Transpiration*. The flow of liquid from the surface of the skin or membrane, an ulcer, &c.

F

Fa′cial (L. *facies*, the face). Belonging to the face; as *facial nerve, facial vein*, &c.

Falx. A scythe, or sickle. The *sickle*-like processes of the dura mater, situated between the lobes of the cerebrum and cerebellum.

Fas′cia (L. *fascis*, a bundle). Literally, a scarf or large band. Hence it is applied to the aponeurotic expansion of a muscle.

Fascic′ulus (L. dim. of *fascis*, a bundle). A little bundle; a handful. Thus, a muscle consists of *fasciculi* of fibres.

Fau′ces. The gullet or upper part of the throat; the space surrounded by the velum palati, the uvula, the tonsils, and the posterior part of the tongue.

Fe′mur, Fem′oris. *Os femoris*. The thigh-bone, the longest, largest, and heaviest of all the bones of the body.

Fenes′tra (Gr. *phainō*, to shine). Literally, a window; an entrance into any place. Hence the terms *fenestra ovalis* and *rotunda*, or the oval and round apertures of the internal ear.

Fi′bre (L. *fibra*, a filament). A filament or thread, of animal, vegetable, or mineral composition.

Fi′bril. A small filament, or fibre, as the ultimate division of a nerve. The term is derived from *fibrilla*, dim. of fibra, a filament.

Fi′brin. A tough fibrous mass, which, together with albumen, forms the basis of muscle.

Fi′bro-car′tilage. Membraniform cartilage: a substance intermediate between proper cartilage and ligament.

Fib′ula. Literally, a clasp, or buckle. It denotes the lesser bone of the leg.

Fil′ament (L. *filum*, a thread). A small thread-like structure, or fibre, as that of a nerve, &c.

Fil′iform (L. *filum*, a thread, *forma*, likeness). Thread-like; applied to the papillæ at the edges of the tongue.

Flex′or (L. *flecto*, to bend). A muscle which bends the part into which it is inserted. Its antagonist is termed *extensor*.

Fluid′ity (L. *fluo*, to flow). The state of bodies when their parts are very readily moveable in all directions with respect to each other.

Flu′ids. Substances which have the quality of fluidity, and are, in consequence, of no fixed shape.

Fol′licle (L. dim. of *follis*, a pair of bellows). Literally, a little bag, or scrip of leather; in anatomy, a very minute secreting cavity.

Fora′men (L. *foro*, to pierce). An opening.

Fos′sa (L. *fodio*, to dig). A ditch or trench; a little depression, or sinus.

Func′tion (L. *fungor*, to discharge an office). The office of an organ in the animal or vegetable economy, as of the heart in circulation, of the leaf in respiration, &c.

Fu′siform (L. *fusus*, a spindle, *forma*, likeness). Spindle-shaped; a term applied to certain muscles.

G

Gall′-bladder. A membranous reservoir, lodged in a fissure on the under surface of the right lobe of the liver, and containing the bile.

Gall′-ducts. These are the *cystic*, proceeding from the gall-bladder; the *hepatic*, proceeding from the liver; and the *ductus communis choledochus*, resulting from the union of the two preceding.

Gan′glion (Gr. *gangglíon*, a nerve-knot). A small nervous centre, or an enlargement in the course of a nerve, sometimes termed a *diminutive brain*.

Gas′ter. The Greek term for the stomach.

Gas′tric (Gr. *gaster*, the stomach). Pertaining to the stomach; as the gastric juice, &c.

Gas′tric Juice. The peculiar digestive fluid secreted by the stomach.

Gel′atine (L. *gelu*, frost). The principle of jelly. It is found in the skin, cartilages, tendons, membranes, and bones. The purest variety of gelatine is *isinglass*.

Gin′givæ. The gums; the reddish tissue which surrounds the neck of the teeth.

Gin′glymus (Gr. *gigglumòs*, a hinge). The *hinge-like* joint; a species of articulation admitting of flexion and extension.

Gland (L. *glans, glandis*, an acorn). A soft body, composed of various tissues, vessels, nerves, &c., usually destined to separate some fluids from the blood.

Gle′noid (Gr. *glēnc*, a cavity, *eidos*, likeness). The name of a part having a shallow cavity, as the socket of the shoulder-joint.

Glob′ules Red (L. dim. of *globus*, a ball). The red colouring matter of the blood; a peculiar animal principle.

Glos′sa, or Glot′ta (Gr. *glōtta*). The tongue; the organ of speech.—*Glosso-*. Terms compounded of this word belong to nerves or muscles attached to the tongue.

Glot′tis. The aperture of the larynx between the arytænoïd cartilages. It is covered by a cartilage called the *epi-glottis*.

Glu′tæus. The name of three muscles of the hip.

Great Sympathet′ic. A nerve formed by a collection of filaments from every nerve which join each other at the adjacent ganglia.

H

Hæm′atosin (Gr. *haimu*, blood). A characteristic constituent of the blood, derived from the globules.

Hæm′orrhage. A rupture of a blood-vessel; a bursting forth of blood; loss of blood.

Haver′sian Tubes. A term given, from the name of their discoverer, to a very complicated apparatus of minute canals found in the substance of bone, and containing medullary matter.

Hepat′ic. A term applied to any part belonging to the liver.

Hu′merus. The bone of the upper-arm.

Hu′mor (L. *humeo*, to be moist). An aqueous substance; as the humors of the eye.

Hy′aloid (Gr.) The name of the membrane which incloses the vitreous humor of the eye.

Hy′dra (Gr. *udor*, water). A polype indigenous in our brooks, destitute of a stomach, brain, viscera, or lungs.

Hy′giene (Gr., to be well). Health; the preservation of health; that part of medicine which regards the preservation of health.

Hyoi′des (the Greek letter *upsilon*). A bone situated between the root of the tongue and the larynx.

Hypo-gas′trium. The lower anterior region of the abdomen.

Hypo-glos′sal. The name of the *lingualis*, or ninth pair of nerves, situated beneath the tongue.

I, J

Ich′or. A thin acrid discharge, issuing from wounds, ulcers, &c.

Jeju′num (L. *jejunus*, hungry). The upper two-fifths of the small intestines, so named from this portion being generally found *empty*.

Il′eum (to turn about). The lower three-fifths of the *small intestines*, so called from their convolutions, or peristaltic motions.

Il′iac-Bone. Another name for the *os innominatum*, derived from the circumstance that this compound bone supports the parts which the ancients called *ilia*, or the flanks.

Il′ium Os. The uppermost portion of the *os iliacum*, probably so named because it seems to support the intestine called the *ileum*.

Il′iac Region. The region situated on each side of the hypogastrium.

In′cus (*an anvil*). A small bone of the internal ear, with which the malleus is articulated; so named from its fancied resemblance to an anvil.

In′dex (L. *indico*, to point out). The fore-finger; the finger usually employed in *pointing* at any object.

Infra-spina′tus. A muscle arising from the scapula below the spine, and inserted into the humerus.

Innomina′tus (L. *in*, priv., *nomen*, name). Hence *Innominatum os*, a bone composed of three portions, viz: 1, The *ilium*, or haunch-bone. 2, The *ischium*, or hip-bone. 3, The *os pubis*, or share-bone.

In′stinct. This convenient term admits of the following significations: 1. The *Instinctive Faculty;* or that faculty which leads the duckling, untaught, into the water; the beaver to build its hut; the bee its comb; the hen to incubate her eggs, &c.; and, 2. The *Instinctive Motions;* or those involuntary actions which are excited mediately through the nerves—a part of the *reflex function*.

Integ′ument (L. *in*, and *tego*, to cover). The covering of any part of the body, as the cuticle, cutis, &c.

Inter-artic′ular. A designation of cartilages which lie within joints, as that of the jaw.

Inter-cos′tal. The name of two sets of muscles between the ribs—the *external* and the *internal*.

Inter-os′sei. Muscles situated between bones; as those between the metacarpal bones of the hand, and the metatarsal bones of the foot.

Inter-ver′tebral. A term applied to the *fibro-cartilage* between the vertebræ.

Intes′tines (L. *intus*, within). That part of the alimentary canal which extends from the stomach to the anus.

I′ris. Literally a rainbow; and hence applied to the *rainbow-like* membrane which separates the anterior from the posterior chamber of the eye.

Is′chium. A spinous process of the os innominatum.

Ju′gular. Belonging to the neck; applied chiefly to the principal veins of the neck.

K

Kingdom. A term denoting any of the principal divisions of nature; thus we have the *organic kingdom*, comprehending substances which organize, and the *inorganic kingdom*, comprehending substances which crystallize.

Knee′-pan. Patella; the small round bone at the front of the knee-joint.

L

La′bia. The lips. They are laterally united by means of two acute angles, which are called their *commissures*.

Lab′yrinth. The name of a series of cavities of the inner ear; viz: the vestibule, the cochlea, and the semi-circular canals.

Lac′ryma. A tear; the fluid secreted by the *lacrymal gland*, and flowing on the surface of the eye.

Lac′teals (L. *lac*, milk.) Numerous minute tubes which *absorb* or take up the chyle, or *milk-like* fluid, from the alimentary canal.

Lac′tic Acid (L. *lac, lactis*, milk.) An acid produced whenever milk, and perhaps most animal fluids, become spontaneously sour.

Lam′ina. Literally, a small plate of any metal. A term applied to the foliated structure of bones or other organs.

La′rynx (Gr. *larungx*, the larynx). The superior part of the trachea, situated immediately under the os hyoïdes.

Latis′simus Dor′si (L. *latissimus;* superl. of *latus*, broad; *dorsum*, the back). A flat muscle, situated on the back and side of the lower part of the trunk. It moves the arm backwards and downwards; or brings forward the body when the hand is fixed.

Lens (L. *lens, lentis*, a bean). Properly, a small roundish glass, shaped like a *lentil*, or bean.

Leva′tor (L. *levo*, to lift up). A muscle which *raises* any part, as the rectus superior. Its antagonist is called *depressor*.

Lig′ament (L. *ligo*, to bind). A membrane of a flexible but compact texture, which connects the articular surfaces of bones and cartilages; and sometimes protects the joints by a capsular envelope.

Lim′bus Lu′teus. A yellow halo surrounding the *foramen of Soemmering*, observed in animals which have the axis of the eyeballs parallel with each other, as in man, the quadrumana, and some reptiles.

Lin′gua (L. *lingo*, to lick). The tongue; the organ of taste and speech.

Liv′er. The largest glandular apparatus in the body, the office of which is to secrete the bile.

Lob′ulus (L. dim. of *lobus*, a lobe). A lobule, or small lobe.

Lon′gus, Lon′gior, Lon′gissimus. Names given to several muscles, to denote their length.

Lum′bi. The loins; the inferior part of the back; whence *Lumbar*, the designation of nerves, arteries, veins, &c., belonging to the region of the loins.

Luxa′tion (L. *luxo*, to put out of joint). Dislocation; or the removal of the articular surface of bones out of their proper situation.

Lymph (L. *lympha*, water). A colourless liquid which circulates in the lymphatics.

Lymphat′ics (L. *lympha*, water). Minute tubes which pervade every part of the body, which they *absorb*, or take up, in the form of *lymph*.

M

Magne′sium. A metal having the colour and lustre of silver.

Malleo′lus (L. dim. of *malleus*, a mallet). The ankle, so called from its resemblance to a mallet.

Mamma′lia (L. *mama*, a teat). The fifth class of the Vertebrata, consisting of animals provided with mammary glands for the suckling of their young after birth.

Mas′seter (Gr. to chew). A muscle which assists in chewing.

Mas′toid (Gr. a breast). Shaped like the breast or nipple; as applied to a *process*, and a *foramen* of the temporal-bone.

Mea′tus (L. *meo*, to pass, to flow). Literally, a passage.

Medul′la. Marrow; a kind of fixed oil, occupying the cavities of bones.

Medul′la Oblongata. The upper enlarged portion of the spinal cord.

Medul′la Spinalis. The spinal marrow or cord.

Medul′lary. The designation of the *white* substance of the brain.

Mes′entery (Gr. between the bowels). The membrane which connects the small intestines and the posterior wall of the abdomen.

Meta-car′pus (Gr. after, the wrist). That part of the hand which is situated between the carpus and the fingers.

Meta-tar′sus. That part of the foot which is situated between the tarsus and the toes.

Mid′riff. *Diaphragm*. The muscle which divides the body into the thorax and the abdomen

Mi′tral Valves (L. *mitra*, a mitre). The name of two valves which guard the left ventricle of the heart.

Mo′lar (L. *mola*, a mill-stone). The double or grinding teeth. Those with two fangs are called bicuspid, or false molars.

Mo′tor (L. *moveo*, to move). A mover; a part whose function is *motion*.

Mucip′arous (L. *mucus*, and *pario*, to produce). Producing mucus; a term applied to the *follicles* of the mucous membranes.

Mu′cus. The liquid secreted by the mucous surfaces, as of the nostrils, intended as a protection to the parts exposed to external influences.

N

Narcot′ics (Gr. stupor). Medicines which induce sleep or stupor, as opiates.

Na′sus. The nose, or organ of smell; whence *nosal*, belonging to the nose.

Nerves (L. *nervus*, a string). White cords arising from the brain or the spinal marrow, and distributed to every part of the system.

Neural′gia. Nerve-ache, or pain in the nerve.

Neu′ron (Gr.). A nerve; a cord arising from the brain or spinal marrow; whence *Neurilemma*, the sheath of a nerve; and *Neurology*, the doctrine of the nerves.

Ni′trogen. *Azote*. An elementary principle, constituting four-fifths of the volume of atmospheric air.

Nu′cleus. The kernel of a nut. The centre around which particles are aggregated.

Nutri′tion (L. *nutrio*, to nourish). The process of nourishing the frame.

O

Obli′quus. Oblique or slanting; not direct, perpendicular or parallel, applied to several muscles.

Obtura′tor (L. *obturo*, to stop up). The name of two muscles of the thigh, and of a nerve.

Oc′ciput (L. *ob caput*). The back part of the head; the part *opposite* to the front or *sinciput*.

Œsoph′agus (Gr. to carry, to eat). A canal leading from the mouth to the stomach.

Oleag′inous (L. *oleum*, oil). That which contains, or resembles, oil.

Olec′ranon. The large *apophysis*, constituting the elbow, or head of the ulna.

Olfac′tory (L. *olfacio*, to smell). Belonging to the smell; the name of the first pair of cerebral nerves, &c.

Omen′tum. The caul; a fold or reflexion of the peritoneum.

Omo (Gr. the shoulder). Words compounded with this term belong to muscles attached to the scapula.

Op′tic. Belonging to the sight.

Orbicula′ris. The name of two muscles of the face.

Or′bit (L. *orbita*, an orbit, a track). The cavity under the forehead, in which the eye is fixed.

Or′gan. A part which has a determinate office in the animal economy.

Organiza′tion. A term applied to a system, composed of several individual parts, each of which has its proper function, but all conduce to the existence of the entire system.

Or′igin (L. *origo*). The commencement of a muscle from any part. Its attachment to the part it moves is called its *insertion*.

Os, Ossis. A bone; a portion of the skeleton, constituting a *passive* organ of locomotion, as distinguished from a muscle, or *active* organ of this faculty.

Ossifica′tion. The formation of bone; the deposition of calcareous phosphate, or carbonate, on the soft solids of animal bodies.

Ot′olites (Gr. the ear, a stone). Calcareous concretions found in the labyrinth of fishes and fish-like amphibia, which, by being in contact with the membranous parts of the labyrinth, increase by their resonance the sonorous vibrations.

Ox′ides. Substances combined with oxygen, without being in the state of an acid.

Ox′ygen. A gas which forms about a fifth of atmospheric air, is capable of supporting flame, and is essential to the respiration of animals.

P

Pal′atum. The palate, or upper wall of the mouth.

Pal′ma. The palm of the hand; the internal soft part of the hand, whence, *palmar*, *palmaris*, belonging to the palm.

Palpe′bra. The eyelid. The utmost edge of the palpebra, out of which the hairs grow, is called *cilium*, a term also applied to the hairs themselves; while the eyebrow, or ridge of hair above the eyelid, is called *super-cilium*.

Pan′creas. A gland, situated transversely across the posterior wall of the abdomen. In cattle it is called the *sweet-bread*.

Pancreat′ic Juice. The peculiar fluid secreted by the pancreas.

Papil′la. The term *papillæ* denotes the small eminences which constitute the roughness of the upper surface of the tongue.

Paral′ysis. Palsy; the total loss, or diminution, of sensation or of motion, or of both.

Parot′id. The name of the large salivary gland situated near the ear.

Par′ies, Pari′etis. The wall of a house, or any other building; whence *Parietal*, belonging to the walls of an organ.

Parva′gum (wandering pair). The name of the eighth pair of nerves, or pneumo-gastric.

Pate-arsen′icale. Arsenical paste, composed of cinnabar, dragon's blood, and arsenious acid, and employed to cauterize cancerous wounds.

Patel′la (L. dim. of *patina*, a pan). Literally, a small pan. The knee-pan.

Pathet′ici (Gr. *passian*). A name given by Willis to the fourth pair of nerves, because the eyes, by means of these, express certain passions.

Pec′toral. (L. *pectus*, the breast). Pertaining to the breast.

Pectoral′is. The name of two muscles of the trunk.

Pel′vis (Gr. *a basin.*) The basin, or large bony cavity which terminates the trunk inferiorily.

Pen′niform (L. *penna*, a feather). Feather-shaped; a term applied to those muscles which have their fibres arranged on each side of the tendon.

Pericar′dium (Gr. *around the heart*). A fibro-serous membrane which surrounds the heart.

Pericra′nium. The periosteum or membrane which covers the bones of the cranium.

Perios′teum. The membrane which surrounds the bones.

Peristal′tic. A term applied to the vermicular contractions of the intestines upon themselves.

Peritonæ′um. The serous membrane which lines the interior of the abdomen, and invests all the viscera contained therein.

Permeabil′ity (L. *per*, through, *meo*, to pass). That property of certain bodies by which they admit the passage of other bodies through their substance.

Pero′ne′ (Gr. *a brooch*). The fibula, or small bone of the leg; whence *Peroneus*, the name of three muscles of the leg.

Perspira′tion (L. *perspiro*, to breathe through). The watery vapour which is constantly passing off through the skin.

Pha′lanx. A battalion in the Macedonian armies, composed of 16,000 men. Hence the term *phalanges* is applied to the bones of the fingers and toes, from their regularity.

Pha′rynx (Gr. *the throat*). A musculo-membranous bag, situated at the back part of the mouth, leading to the stomach.

Phre′nes (Gr. *the mind*). The diaphragm; so called because the ancients supposed it to be the seat of the mind. Hence the term *Phrenic*, a designation of the internal respiratory nerve, which goes to the diaphragm.

Phrenol′ogy (Gr. *an account*). A description of the mind; a science, introduced by Gall and Spurzheim, by which particular characters and propensities are indicated by the conformation, and protuberances, of the skull.

Physiol′ogy (Gr. *phusis*, nature, *logos*, an account). The science which treats of the properties of organic bodies, animal and vegetable, of the phenomena which they present, and of the laws which govern their actions

Pi′a Ma′ter. A vascular membrane, investing the whole surface of the brain.

Pigmen′tum Ni′grum (L. *pingo*, to paint). A dark brown substance, which covers the outer and inner surface of the choroid membrane.

Pin′na. The fin of a fish. A portion of the external ear, termed *pinna auriculæ*, or the auricle, representing a kind of funnel, which collects the vibrations of the atmosphere. The other portion is termed *meatus*, and represents a tube, which conveys the vibration to the tympanum.

Pi′siform (L. *pisum*, a pea, *forma*, likeness). Pea-like; the designation of the fourth bone of the first row of the carpus.

Pitu′itary Membrane. A designation of the Schneiderian membrane, which lines the cavities of the nose.

Plex′us (L. *plecto*, to weave). A kind of net-work of blood-vessels, or nerves.

Pneu′mo-Gas′tric Nerves (Gr. *pneumōn* the lung, *gastér* the stomach). The par vagum, nervi vagi, or eighth pair of nerves, distributed to the lungs and the stomach.

Por′tal Circula′tion. A subordinate part of the venous circulation, in which the blood makes an additional circuit before it joins the rest of the venous blood.

Por′tal Vein (L. *vena portæ*). A vein originating from the organs within the abdomen.

Por′tio Du′ra. The *hard portion* of the seventh pair of nerves, or *facial*.

Por′tio Mol′lis. The *soft portion* of the seventh pair of nerves, or *auditory*.

Potas′sium. The metallic base of the well-known alkaline substance potassa.

Prism (Gr. *prisma*, from *priō*, to saw). A solid glass in the form of a triangle, so termed from its *separating* a ray of light into its constituent parts.

Pro′cess. *Apophysis.* A process, or eminence of a bone. Also, a lobe, or portion of the brain.

Profun′dus. Literally, deep, or deep-seated. A designation of one of the flexors of the fingers, from its being situated more deeply than the flexor sublimis.

Prona′tion (L. *pronus*, bending downward). The act of turning the palm of the hand downwards, by rotating the radius upon the ulna by means of the pronator muscles.

Prona′tor (L. *pronus*, bending downward). The name of two muscles which turn the radius and the hand inwards and downwards.

Protu′berance (L. *pro*, before, *tuber*, a swelling). An eminence, or projecting part.

Prox′imate Prin′ciple. A term applied, in analyzing any body, to the principle which is *nearest* to the natural constitution of the body, and more immediately the object of sense, as distinguished from intermediate or ultimate principles. *Ultimate principles* are the elements of which proximate principles are composed.

Pso′as (Gr. *psóai*, the loins). The name of two muscles of the loins.

Pul′monary, *pulmonic*, (L. *pulmo*, the lungs). Relating or belonging to the lungs.

Pulse (L. *pulsus*, a stroke). A beating or striking; and, hence, the stroke or beat of an artery.

Punc′tum (L. *pungo*, to prick). A point; that which is without extent.

Punc′ta Lachryma′lia. The external commencements of the lacrymal ducts.

Pupil′la (L. dim. of *pupa*, a puppet). The pupil, or the round aperture in the centre of the iris of the eye.

Pylo′rus (Gr. *púlē*, a gate; *ōra*, care). Literally, a *gate-keeper*. The lower and con tracted orifice of the stomach, guarding the entrance into the bowels.

Pyramidal′is. The name of several muscles, from their pyramidal shape.

Q

Quadra′tus. The name of several muscles, derived from their square, or oblong, form.

R

Ra′chis (Gr. *ráchis*). Properly, *Rhachis*. The spine; the vertebral column.

Ram′ification (L. *ramus*, a branch, *fio*, to become). The issuing of a small branch from a large one, as of the minute branches from the larger arteries.

Ra′mus. A branch of a tree; the designation of portions of several bones

Rec′tum (L. *rectus*, straight). The last portion of the intestines.

Rec′tus (L. *straight*). The name of several muscles.

Refrac′tion (L. *refractus*, broken back). That property of light, by which a ray becomes bent, or *refracted*, when passing from a rarer into a denser medium, and *vice versá*.

Respira′tion. The function of breathing.

Ret′ina (L. *rete*, a net). The *net*-like expansion of the optic nerve on the inner surface of the eye.

Ri′ma. A fissure, a crack, or cleft; a narrow longitudinal opening.

Rima Glottidis. The fissure of the glottis, or the longitudinal aperture through which the air passes into and from the lungs.

Roden′tia (L. *rodo*, to gnaw.) Glires, or gnawing animals, as the beaver, the hamster, the rat, &c.

Rota′tion (L. *rota*, a wheel). The motion of a wheel; the revolving motion of a bone round its axis.

Rota′tor (L. *rota*, a wheel). The name of a muscle which *wheels* any part round.

Ru′ga. A wrinkle. Hence the terms *rugose*, wrinkled, and *rugosity*, applied to a wrinkled surface, as the mucous membrane of the stomach.

Ruminan′tia (L. *rumino*, to chew the cud. Animals which chew the cud, as the deer.

Rumina′tion. A voluntary regurgitation of food for further mastication; peculiar to the ox, sheep, and other animals having numerous stomachs; it is commonly called *chewing the cud.*

S

Sac (L. *saccus*, a bag). A term applied to a small cavity, as the lacrymal sac.

Sac′culus (L. dim. of *saccus*, a bag). A little bag.

Sa′crum (L. *Sacred*). The bone which forms the basis of the vertebral column, so called from its having been offered in sacrifice, and hence considered *sacred*.

Sacro-. A term applied to parts connected with the sacrum; hence we have *sacro*-iliac symphysis, *sacro*-spinal ligament, *sacro*-vertebral angle, &c.

Sali′va. The insipid, transparent, viscous liquid, secreted by the salivary glands, principally the parotid.

San′guis. Blood; the fluid which circulates in the heart, arteries, and veins.

Saphe′na (Gr. *saphès*, manifest). The name of two *conspicuous* veins of the lower extremities.

Sarto′rius (L. *sartor*, a tailor). The muscle by means of which the tailor crosses his legs.

Sca′la. Literally, a ladder, or a flight of stairs. Hence *Scalæ of the cochlea*, the two cavities which result from the presence of the spiral septum of the cochlea.

Scale′nus (Gr. *skalēnòs*, a geometrical figure with three unequal sides). The name of two muscles, the *anticus* and the *posticus*, which bend the head and neck, &c.

Scaphoi′des (Gr. *skaphē*, a skiff; *eīdos*, likeness). Resembling a scapha, or skiff; the designation of a bone of the carpus, and of the tarsus.

Scap′ula. The shoulder-blade.

Schneide′rian Membrane. The *pituitory membrane*, which secretes the mucus of the nose; so named from Schneider, who first described it.

Sciat′ic Nerve. The termination of the sacral or sciatic plexus; it is the largest of all the nerves.

Sclerot′ica (Gr. *sklērôs*, hard). The dense fibrous membrane which, with the *cornea*, forms the external tunic of the eye-ball.

Seba′ceous (L. *sebum*, suet). Suety; a term applied to *follicles* which secrete a peculiar oily matter, and are abundant in some parts of the skin, as in the nose, &c.

Secre′tion (L. *secerno*, to separate). A substance *secreted* or separated from the blood, by the action of a secreting organ.

Septum (L. *sepes*, a hedge). A partition which separates two cavities.

Serra′tus (L. *serra*, a saw). The name of three muscles of the side and back.

Se′rum. The thin yellowish fluid constituent of the blood.

Ses′amoid (Gr. *sesámē*, an Indian bean, *eīdos*, likeness). The designation of small bones found at the first joint of the thumb and of the great-toe.

Sig′moid (the Greek letter Σ, *sigma*, and *eīdos*, likeness). Resembling the letter Σ, as applied to a *flexure of the colon*, where it forms a double curve in the iliac region; and to the *semi-circular valves*, which guard the orifice of the pulmonary artery, and of the aorta.

Sin′ciput. The fore part of the head. The back part is called *occiput*.

Sin′ew. The ligament which joins two bones.

Si′nus. A gulf. Hence it denotes a cavity or cell within the substance of a bone, as of the forehead; also, a large venous canal, as those of the dura mater.

Skel′eton (Gr. *skéllō*, to dry up). The dry bony frame-work of an animal, which sustains the other organs.

So′dium. A peculiar metal, constituting the basis of soda.

Soft Pal′ate. A soft moveable curtain, appended to the extremity of the vault of the palate, and separating the mouth from the pharynx.

So′leus (L. *solea*, a sole). A muscle of the leg, shaped like the sole-fish.

Sphe′noid (Gr. *sphèn*, a wedge, *eīdos*, likeness). Wedge-like, as applied to a bone of the skull, which *wedges in* and locks together most of the other bones.

Sphinc′ter (Gr. *sphinggo*, to contract). A muscle, whose office it is to close the aperture around which it is placed.

Spi′na. Literally, a thorn: hence it is sometimes applied to the back-bone, from the *thorn-like* processes of the vertebræ.

Spi′nal Cord. *Medulla spinalis.* The medullary matter contained within the *spina*, or vertebral column.

Spleen. A spongy organ situated at the left and behind the stomach.

Splenius. A muscle of the back.

Splint-bone. The fibula, or small bone of the leg; so named from its resembling a surgical splint.

Sta'pes. Literally, a stirrup. A stirrup-like bone of the internal ear.

Ster'num. The breast-bone.

Stri'a. A streak or groove. Hence *striated*, streaked or grooved.

Stu'por (L. *stupeo*, to be senseless). A state of insensibility.

Stye (L. *stihan*, Saxon, a springing up). *Stian*. A little inflammatory tumor on the eye-lid.

Sty'loid (Gr. *stūlos*, a pillar, or pencil, *eĩdos*, likeness). The name of a *pencil-like* process of the temporal-bone.

Sub-. A Latin preposition, denoting a position *beneath* any body.

Sub-cla'vian. Situated under the clavicle.

Sub-cla'vius. A muscle arising from the cartilage of the first rib, and inserted into the lower surface of the clavicle.

Sub-cuta'neous. Beneath the skin.

Sub-lin'gual. Beneath the tongue.

Sub-max'illary. Beneath the jaw.

Sub-scapula'ris. A muscle arising from all the internal surface of the scapula, and inserted into the humerus.

Su'dor (L. *sudo*, to sweat). Sweat; the vapour which passes through the skin, and condenses on the surface of the body.

Sudorif'erous Canals. Minute spiral follicles, distributed over the whole surface of the skin, for the secretion of the sweat.

Superfi'cial. That which is upon the surface.

Supina'tion (L. *supinus*, lying with the face upwards). The act of turning the palm of the hand upward, by rotating the radius upon the ulna. The opposite action is called *pronation*.

Supina'tor (L. *supinus*, lying with the face upwards). The name of a muscle which turns the palm of the hand upwards.

Su'ra. The calf of the leg, consisting principally of the soleus and gastrocnemius muscles.

Su'ture (L. *suo*, to sew). A seam; the junction of the bones of the cranium by a serrated line, resembling the stitches of a seam.

Sympathet'ic Nerve. A nerve consisting of a chain of ganglia, extending along the side of the vertebral column from the head to the coccyx, communicating with all the other nerves of the body, and supposed to produce a *sympathy* between the affections of different parts.

Syno'via (Gr. *ōòn*, an egg). A peculiar liquid found within the capsular ligaments of the joints, which it lubricates.

Sys'tole (Gr. *sustéllō*, to contract). The contraction of the heart, auricles, and arteries; opposed to *diastole*, or their dilatation.

T

Tab'ula Vi'trea. The glassy table; a term applied to the dense internal plate of the skull.

Tar'sus. The instep; the space between the bones of the leg and the metatarsus.

Tears. The peculiar fluid which lubricates the eye.

Tem'pora (L. pl. of *tempus*, time). The temples, or that part of the head on which the hair generally begins to turn gray, thus indicating *the age;* whence *temporal*, pertaining to the temples, as temporal bones.

Tena'city (L. *teneo*, to hold). The degree of force with which the particles of bodies cohere, or are held together.

Ten'don (Gr. *téinō*, to stretch). A fibrous cord at the extremity of a muscle, by which the muscle is attached to a bone.

Ten'sor (L. *tendo*, to stretch). A muscle which *stretches* any part.

Tento'rium (L. *tendo*, to stretch). A tent, or pavilion, as *Tentorium cerebelli*, a roof of dura mater thrown across the cerebellum. In leaping animals, it is a bony tent.

Te'res. Long and round. The name of two muscles, the *major* and the *minor*, which arise from the scapula, and are inserted into the humerus. They move the arm in various directions.

The'nar (Gr. *thénar*). The palm of the hand. A muscle extending the thumb.

Tho'rax (Gr. *thórax*). The chest; or that cavity of the body which contains the heart and lungs.

Thora'cic Duct. The great trunk formed by the junction of the absorbent vessels.

Thy'roid (Gr. *thureòs*, a shield). The name given to a shield-shaped cartilage of the larynx, and of a gland situated on the trachea.

Tib'ia. Literally, a flute or pipe. The shin-bone; or the great bone of the leg.

Tib'ial, *tibialis*, pertaining to the tibia.

Tis'sue. A web, or web-like structure, constituting the elementary structures of animals and plants.

Ton'sils (L. *tondeo*, to clip, or shear). The round glands situated in the thorax, between the pillars of the velum palati.

Trach'ea (Gr. *trachus*, rough). The wind-pipe. The term is derived from the inequality of its cartilages.

Tract (L. *traho*, to draw). A drawing in length; a region; a space.

Transversa'lis (L. *transversus*, across). That which is placed across or crosswise, applied to muscles.

Trape'zius. A muscle so named from its lozenge form.

Tri'ceps. Having three heads. Applied to several muscles.

Tricus'pid. Having three points; a term applied to three triangular folds or *valves* situated between the right auricle and the right ventricle of the heart.

Trifa'cial. Triple-facial; a term applied to the fifth pair of nerves, the grand sensitive nerve of the head and face.

Trochan'ter (Gr. *trocháō*, to run or roll). The name of two processes of the thigh-bone —the *major* and the *minor*.

Troch'lea (Gr. *tróchos*, a wheel). A kind of cartilaginous pulley. Hence *Trochlearis*, a name of the obliquus superior, or that muscle of the eye which passes through the *trochlea* or pulley.

Tu'nic. The upper garment of the Romans. Hence it is applied to several membranes of the body.

Tur'binated Bones (L. *turbo*, a top). Two bones of the nostrils, so called from their being formed in the shape of a top, or inverted cone. They are also called the *inferior spongy bones*, to distinguish them from the upper spongy bones.

Tym'panum (Gr. *túmpanon*, a drum). The drum of the ear.

U

Ul'na (Gr. *ōlénē*, the cubit). The large bone of the fore-arm, so named from its being often used as a measure, under the term *ell*.

Ulna'ris (L. *ulna*, the cubit). The name of two muscles of the fore-arm.

Un'ciform (L. *uncus*, a hook, *forma*, likeness). A bone of the carpus, or wrist, having a *hook-like* process.

Unnamed Bones. *Ossa innominata*. Two large bones, forming the sides of the pelvis, and so called from the difficulty of explaining them under one name.

Ur'ic Acid. *Lithic acid*. A common constituent of urinary and gouty concretions.

Uve'a (L. *uva*, grape). The posterior surface of the iris, so called from its resemblance in colour to a ripe grape.

U'vula (L. dim. of *uva*, a grape). The pendulous body which hangs down from the middle of the soft palate.

V

Vaccina'tion (L. *vacca*, a cow). The act of inserting vaccine matter; inoculation for the cow-pox.

Vac'cuum (L. *vaccus*, empty). Literally, an empty place. This term generally denotes the interior of a close vessel, from which the atmospheric air and every other gas has been extracted.

Valve (L. *valvæ*, folding-doors). A close lid affixed to a tube or opening in some vessel, by means of a hinge, or other moveable joint, and which can be opened only in one direction. Hence it signifies a little membrane which prevents the return of fluid in the blood-vessels and absorbents.

Val'vula (L. dim. of *valve*). A little valve.

Vas, Va'sis. Plural *Vasa*. A vessel, or any utensil to hold liquor.

Vas'cular System. That part of the animal economy which relates to the vessels.

Vas'tus. A term applied to two large muscles of the leg.

Ve'na. A vein; an elastic tube, which conveys the dark or venous blood from the arteries to the heart.

Ve'nous. Belonging to a vein.

Ventric'ulus (L. dim. of *venter*, the belly). The term *ventricle* is also applied to two cavities of the heart, and to several cavities in other parts of the body.

Ver'miform (L. *vermis*, a worm, *forma*, likeness). Worm-like.

Vermic'ula. Having a worm-like motion.

Ver'tebra L. (*verto*, to turn). A bone of the spine, so named from its *turning* upon the adjoining one.

Ver'tebral. Connected with the vertebra.

Vertebra'ta. Animals which have an internal skeleton, supported by a vertebral column.

Ves'icle (L. dim. of *vesica*, a bladder). A little bladder.

Ves'tibule (L. *vestibulum*, a threshbold). A small oval cavity of the internal ear, so named from its forming an entry to the cochlea and semi-circular canals.

Vill'us. Literally, the shaggy hair of beasts. Some of the membranes of the body, as the mucous membrane of the intestinal canal, present a surface of minute papillæ, termed *villi*, villosities, resembling a downy tissue, continually covered with fluid.

Vis'cus. Pl. *Viscera*. A bowel, or intestine. Any organ which has an appropriate use.

Vit'reous Body (L. *vitrum*, glass). *Vitreous humor*. A transparent mass, resembling melted glass, occupying the globe of the eye, and inclosed in the hyaloïd membrane.

Vo'mer (*a plough-share*). A bone of the nose, forming the partition between the nostrils, and so named from its resemblance to a plough-share.

W

Warm-blooded. A term applied to the mammalia and birds which have a two-fold circulation.

X

Xyph'oid (Gr. *xíphos*, a sword, *eĩdos*, likeness). Sword-like; a term applied to the cartilage of the sternum.

Z

Zoöl'ogy (Gr. *zōōn*, an animal, *lógos*, a description). That branch of Natural History which treats of animals.

Zygomat'icus (Gr. *zugòs*, a yoke). A name given to two muscles of the face, which are attached to the *zygoma* or arch formed by processes of the bones.

THE END.

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